Rapport de veille n° 98

Aéraulique et COVID-19

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Loiseau, A., Davit-Beal, T., Brezulier, D.
Are protective measures against Covid-19 still active in orthodontic practices? A cross-sectional online survey of French orthodontists three years on from the pandemic.
PLoS One, Vol. **19** n°(7), (2024)

Purpose The Covid-19 epidemic has imposed profound changes on the practice of orthodontics. It was in this anxiety-inducing context that drastic measures were imposed on orthodontists. The main aim of this online survey is to highlight the measures that are still in place in French orthodontic practices three years after the emergence of the pandemic. Methods A cross-sectional online survey was distributed to French orthodontists from march to June 2023. The questionnaire, consisting of 32 questions, was divided into five sections covering habits before and after the pandemic, and the feelings of professionals. Results In this survey 230 complete answers were recorded. Three years later, the daily pace had returned to its pre-crisis level. Disinfection and aeration times were still present ($p < 0.001$). Orthodontists maintained and generalized the use of protective glasses ($p = 0.17$) and visors ($p < 0.001$). The same was true for the FFP2 mask and its frequency of change, as well as rigorous hand washing. Finally, the dedicated layout of the practices was maintained: protective screen, filtration system, supply of SHA, travel paths, removal of magazines (for all, $p < 0.001$). Conclusion This study shows that the professional practices imposed by the Covid-19 crisis have been adopted by the majority of French orthodontists, and now appear to be anchored in their routine practice. Trial registration number opinion n degrees 2023-004, dated 01.25.2023.

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Crews, C., Angwaawie, P., Abdul-Mumin, A., Yabasin, I. B., Attivor, E., Dibato, J.*, et al.*
Assessing ventilation through ambient carbon dioxide concentrations across multiple healthcare levels in Ghana.
PLOS Global Public Health, Vol. **4** n°(8), (2024)

Infection prevention and control (IPC) measures safeguard primary healthcare systems, especially as the infectious disease landscape evolves due to climate and environmental change, increased global mobility, and vaccine hesitancy and inequity, which can introduce unexpected pathogens. This study explores the importance of an "always-on," low-cost IPC approach, focusing on the role of natural ventilation in health facilities, particularly in low-resource settings. Ambient carbon dioxide (CO_2) levels are increasingly used as a measure of ventilation effectiveness allowing for spot checks and targeted ventilation improvements. Data were collected through purposive sampling in Northern Ghana over a three-month period. Levels of CO_2 ppm (parts per million) were measured by a handheld device in various healthcare settings, including Community-Based Health Planning and Services (CHPS) facilities, municipal and teaching hospitals, and community settings to assess ventilation effectiveness. Analyses compared CO_2 readings in community and hospital settings as well as in those settings with and without natural ventilation. A total of 40 facilities were evaluated in this study; 90% were healthcare facilities and 75% had natural ventilation (with an open window, door or wall). Facilities that relied on natural ventilation were mostly community health centers (60% vs 0%) and more commonly had patients present (83% vs 40%) compared with facilities without natural ventilation. Facilities with natural ventilation had significantly lower CO_2 concentrations (CO_2 ppm: 663 vs 1378, $p = 0.0043$) and were more likely to meet international thresholds of $CO_2 < 800$ ppm (87% vs 10%, $p = <0.0001$) and $CO_2 < 1000$ ppm (97% vs 20%, $p = <0.0001$). The adjusted odds ratio of low CO_2 in the natural facilities compared with non-natural were: odds ratios, OR (95% CI): 21.7 (1.89, 247) for $CO_2 < 800$ ppm, and 16.8 (1.55, 183) for $CO_2 < 1000$ ppm. Natural ventilation in these facilities was consistently significantly associated with higher

likelihood of low CO2 concentrations. Improved ventilation represents one cost-effective layer of IPC. This study highlights the continuing role natural ventilation can play in health facility design in community health care clinics. Most health facilities met standard CO2 thresholds, particularly in community health facilities. Further research is needed to optimize the use of natural ventilation. The use of a handheld devices to track a simple metric, CO2 levels, could improve appreciation of ventilation among healthcare workers and public health professionals and allow for them to target improvements. This study highlights potential lessons in the built environment of community primary health facilities as a blueprint for low-cost, integrated multi-layer IPC measures to mitigate respiratory illness and anticipate future outbreaks.

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Linge, K. L., Chen, J., Mikszewski, A., Buonanno, G., Morawska, L., Jermy, M.
Case studies using a simple airborne infection risk calculator to minimize COVID-19 infection risk: Common approaches and challenges.
Building and Environment, Vol. **265**, (2024)

Following the recognition of the role of airborne transmission in the spread of SARS-CoV-2, the role of building ventilation in minimising indoor respiratory events has become of significant interest, with numerous risk assessment tools developed to understand infection risk in different indoor environments. To date there has been limited retrospective analysis of how such tools were applied to assess indoor infection risk and inform building occupancy during the COVID-19 pandemic. In this paper we document case studies from Australia and New Zealand using one such risk assessment tool, the Airborne Infection Risk Calculator (AIRC), and describe how the AIRC was used to assess COVID-19 risk in different indoor settings and how users customized the tool for their own purposes. While inherent uncertainties mean the AIRC model could not calculate the exact risk in any of the case studies, the model's framework enabled objective discussion about the role of ventilation in infection risk reduction and public health. Future use of tools such as the AIRC would be improved with development of policies or regulations that promote or require a standardized approach for this assessment, translation of improvement in ventilation in a room or building scale into overall public health benefits, and endorsement of such tools by Global and/or National health authorities.

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Karumuna, B. V., Hao, L.
CO2 Concentration Assessment for Infection Monitoring and Occupancy Analysis in Tanzanian COVID-19 Isolation Centers.
Buildings, Vol. **14** n°(7), (2024)

Monitoring of IAQ is one of the foundations of the preventative actions prompted by the worldwide recognition of COVID-19 transmission. The measurement of CO2 has emerged as one of the most popular, dependable, and easy ways to indirectly evaluate the state of indoor air renewal. Reducing the risk of respiratory diseases transmitted by aerosols is attainable through implementing and validating prevention measures made possible by CO2 control. Isolation centers are like health facilities in that they are linked to IAQ, and the presence of natural ventilation can significantly improve the circulation of fresh air, which speeds up the removal of contaminants. This is true even though healthcare facilities are among the environments with the highest rate of COVID-19 propagation. Our investigation revealed, however, that no substantial critical data on air quality in Tanzanian isolation centers is presently available. The process of metabolic CO2 creation and accumulation within health isolation center cubicles was investigated in this study. Crucially, we suggest comparing settings under various conditions using the indicator ppm/patient. In this research, we experimentally assessed the value of changing a few HVAC system characteristics. We looked at the data to see how well the filtration system worked concerning the submicron particle concentration. Study recommendations for CO2 detectors and ways to reduce infection risk in shared isolation center cubicles are provided. We also show the correlation between particle size and CO2 concentration, the correlation between

CO2 concentration derivatives and air volume presented per patient in isolation cubicles, the correlation between patient occupancy and CO2 concentration levels in isolation cubicles, and how to improve air quality by adjusting the patient's bed position. The study also found that for exposure lengths of two to three hours, a typical hospital cubicle with fifty to one hundred people should have an average interior CO2 value of less than 900 ppm. Carers' length of stay in the hospital substantially impacted the permissible CO2 concentration. By establishing a connection between indoor air monitoring and healthcare goals, this study will aid in determining the feasibility of establishing regulations for interior CO2 content depending on occupancy settings, strengthening preventive efforts against COVID-19. In the post-pandemic era, it will be essential to find ways to make health facilities air cleaner so that infectious diseases cannot spread in the future.

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Irungbam, M., Shrivastava, R., Prasad, J., Mudgal, A., Dubey, A., Singh, V. K.*, et al.*
Effectiveness of air purifier in reducing the viral load in atmospheric air of room of COVID-19 patients.
Research Square, (2024)

This study evaluates the effectiveness of air purifiers in reducing the viral load of SARS-CoV-2 in the atmospheric air of rooms housing COVID-19 patients. Air samples were collected using an air sampler before and after the implementation of air purifiers equipped with high-efficiency particulate air (HEPA) filters. Additionally, swab samples were collected from various filters within the air purifiers to assess viral RNA presence. The results demonstrate the detection of SARS-CoV-2 RNA in particulate matter samples collected before air purification, indicating viral presence in the atmospheric air. Moreover, viral load was inversely correlated with the flow rate of the air sampler, with higher flow rates associated with increased viral load. Swab samples from air purifier filters revealed positive RT-PCR results for both the E-gene and RdRp gene of SARS-CoV-2, highlighting viral retention within the filtration system. Notably, the photo-catalyst oxidation filter demonstrated a reduction in viral RNA presence over time. Following air purification, SARS-CoV-2 RNA was undetectable in samples collected from the PVDF membrane filter at lower flow rates, while positive results were obtained at higher flow rates. These findings underscore the potential of air purifiers in reducing viral load and mitigating airborne transmission within healthcare settings. Further research is warranted to optimize air purification strategies and assess long-term efficacy in controlling viral dissemination.

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Sultan, Z., Luhung, I., Aung, N. W., Uchida, A., Natarajan, A., Puramadathil, S.*, et al.*
Effectiveness of triethylene glycol disinfection on airborne MS2 bacteriophage under diverse building operational parameters.
Indoor Environments, Vol. **1** n°(3), (2024)

Research on triethylene glycol (TEG) use to disinfect airborne microorganisms have been conducted in non-realistic chamber settings. This study assesses how air temperature, humidity, HVAC settings, and filtration impact TEG's effectiveness in deactivating a common SARS-CoV-2 substitute, MS2 bacteriophage, in a simulated non-occupied office-sized chamber. The chamber was served by a dedicated HVAC system operating at 22.0, 23.5 and 25.0 °C, at 40, 55 and 70 % relative humidity, at 0, 3 and 6 air change per hour (ACH) recirculation, at 0.8, 2.5 and 5.0 ACH outdoor ventilation and at no, MERV8 and MERV14 filtration status. Airborne MS2 log10 reductions in the presence of TEG increased linearly over time and we noted a higher MS2 inactivation rate with higher TEG concentration. The estimated TEG concentration needed for a one-log inactivation of the MS2 within an hour was 0.44 mg/m3. The efficacy of TEG declined with the increase in temperature from 22.0 to 25.0 °C, peaked at 55 % RH, increased with higher recirculation rates but decreased with increasing ventilation rates and higher efficiency filters. The results of our study suggest that the optimum environmental and building conditions for TEG performance is at 22.0 or 23.5 °C air temperature, 55 % relative humidity, 0.8 ACH ventilation rate and 6 ACH recirculation rate. By conducting

experiments in simulated office conditions, this study closes significant knowledge gaps in TEG performance application.

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Ismail, N. D., Tan, H., Dzarfan Othman, M. H., Kek, H. Y., Nyakuma, B. B., Woon, K. S.*, et al.*
Energy-efficient ventilation strategies at hospital front desks for minimizing infectious particle dispersion: Considering patient postures and airflow optimization.
Energy, Vol. **307**, (2024)

This research presents a novel examination of infectious particle dispersion at hospital front desks, analysing the impact of different patient postures on particle dynamics. It evaluates the efficacy of various ventilation strategies in mitigating particle spread within this high-risk area. Specifically, this study innovatively assesses particle dispersion associated with three common patient postures: upright standing, sitting in a wheelchair, and lying on a mobile bed. Results showed the baseline ventilation that considers the upright standing patient has the highest particles (34) adhered on the nurse. Particle adherence decreases with the sitting (29 particles) and lying postures (20 particles), underscoring the significant influence of human posture on particle distribution. The key contribution of this study is the identification of an optimized ventilation strategy which installs low-level wall-mounted air supply diffusers and ceiling-mounted exhaust grilles, as demonstrated in Case 3. This strategy effectively reduces particle deposition on the nurses and visitors by 52.9 % and 40 %, respectively. These findings advocate for practical infection control measures, like barriers between nurses and patients, to better protect healthcare workers. The study also suggests that future research should account for more crowded environments and occupant movement to better reflect real-world conditions at hospital front desks.

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Law, C. K., Lai, J. H. K., Ma, X. D., Sze-To, G. N.
Enhancing indoor air quality: Examination of formaldehyde adsorption efficiency of portable air cleaner fitted with chemically-treated activated carbon filters.
Building and Environment, Vol. **263**, (2024)

The pursuit of salubrious living environments necessitates a holistic approach to assuring indoor air quality. This entails considering not only particulate matter but also gaseous pollutants, particularly formaldehyde - a carcinogenic and prevalent pollutant in household environment. In addressing the persistent challenge in balancing efficiency, operating costs and environmental impact in formaldehyde removal, our study pioneers to empirically explore and compare the relationship between Carbon Tetrachloride Activity (CTC), Clean Air Delivery Rate (CADR), and Cumulate Clean Mass (CCM) in the context of formaldehyde adsorption, using both raw and 2-Imidazolidone-treated activated carbon (AC) filters fitted in a Portable Air Cleaner (PAC). Our experimental results show that the formaldehyde CADRs of an air cleaner with chemically-treated CTC70 and CTC100 filters were about 251 m3/h 3 /h and 286 m3/h 3 /h respectively, representing an increase of 1.52 and 2.5 times over untreated filters, with the treated CTC100 AC filters outperforming the CTC70 filters by approximately 12 percent under new condition. While the precise mechanisms by which 2-Imidazolidone enhances the performance of AC filters are still unknown, these findings provide an first-of-its-kind directive for future research on the interplay among the parameters (CTC, CADR and CCM) of PACs, casting a foundation for further investigations that aim at optimizing the performance of AC filters, thereby making significant strides in the enhancement of indoor air quality.

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Hao, B., Hu, Y., Adams, W. G., Assoumou, S. A., Hsu, H. E., Bhadelia, N.*, et al.*
A GPT-based EHR modeling system for unsupervised novel disease detection.
J Biomed Inform, Vol. **157**, (2024)

Objective To develop an Artificial Intelligence (AI)-based anomaly detection model as a complement of an “astute physician” in detecting novel disease cases in a hospital and preventing emerging outbreaks. Methods Data included hospitalized patients (n = 120,714) at a safety-net hospital in Massachusetts. A novel Generative Pre-trained Transformer (GPT)-based clinical anomaly detection system was designed and further trained using Empirical Risk Minimization (ERM), which can model a hospitalized patient’s Electronic Health Records (EHR) and detect atypical patients. Methods and performance metrics, similar to the ones behind the recent Large Language Models (LLMs), were leveraged to capture the dynamic evolution of the patient’s clinical variables and compute an Out-Of-Distribution (OOD) anomaly score. Results In a completely unsupervised setting, hospitalizations for Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection could have been predicted by our GPT model at the beginning of the COVID-19 pandemic, with an Area Under the Receiver Operating Characteristic Curve (AUC) of 92.2 %, using 31 extracted clinical variables and a 3-day detection window. Our GPT achieves individual patient-level anomaly detection and mortality prediction AUC of 78.3 % and 94.7 %, outperforming traditional linear models by 6.6 % and 9 %, respectively. Different types of clinical trajectories of a SARS-CoV-2 infection are captured by our model to make interpretable detections, while a trend of over-pessimistic outcome prediction yields a more effective detection pathway. Furthermore, our comprehensive GPT model can potentially assist clinicians with forecasting patient clinical variables and developing personalized treatment plans. Conclusion This study demonstrates that an emerging outbreak can be accurately detected within a hospital, by using a GPT to model patient EHR time sequences and labeling them as anomalous when actual outcomes are not supported by the model. Such a GPT is also a comprehensive model with the functionality of generating future patient clinical variables, which can potentially assist clinicians in developing personalized treatment plans.

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Peerless, K., Ullman, E., Cummings, K. J., Stoltey, J., Epson, E., Kim, J. J.*, et al.*

Indoor Air Quality Assessments in 10 Long-Term Care Facilities During the COVID-19 Pandemic, California, 2021–2023.

Journal of the American Medical Directors Association, (2024)

Objectives This study aimed to assess indoor air quality (IAQ) in long-term care facilities (LTCFs) in California during the COVID-19 pandemic and evaluate their implementation of IAQ best practices described by public health authorities to control respiratory pathogen transmission via inhalation. Design This observational study conducted IAQ assessments in a convenience sample of LTCFs to gather qualitative data on the implementation of IAQ best practices. The design included 5 pilot visits to develop a standardized method of data collection and then systematic data collection at 10 facilities. Setting and Participants The study focused on 10 LTCFs across California, chosen from facilities that responded to flyers advertising free IAQ assessments. Some of the facilities had previously experienced COVID-19 outbreaks affecting residents and staff. Methods State health department industrial hygienists performed site visits to collect data on each facility's heating, ventilation, and air-conditioning (HVAC) system operation, outdoor air introduction, recirculated air filtration, use of portable air cleaners, and directional airflow in isolation areas to evaluate implementation of IAQ best practices in each of these areas. Qualitative data were obtained through visual inspections and interviews with maintenance personnel. Results Findings indicated suboptimal implementation of IAQ best practices across the assessed facilities: no facility operated HVAC systems continuously, 40% had all outdoor air dampers open, 20% used MERV-13 or higher rated filters, 20% used portable air cleaners, and 20% performed directional airflow assessment and management for isolating COVID-19 cases. Conclusions and Implications Most LTCFs assessed were not adhering to IAQ best practices, highlighting a significant opportunity for improvement. IAQ best practices described in this study are achievable with existing systems and are critical for reducing virus transmission through the air in LTCFs. The findings underscore the need for more systematic assessments and improvements in IAQ within LTCFs to protect staff and residents.

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Yoshihara, J., Yamanaka, T., Choi, N., Kobayashi, T., Kobayashi, N., Fujiwara, A.
Infection-prevention performance of local exhaust ventilation under three different underfloor air distribution systems during a face-to-face conversation.
Building and Environment, Vol. **265**, (2024)

This study proposes using a local exhaust ventilation system (LEV) to prevent airborne infections, especially for short-range conversations. We compared the performance of a hood in three different underfloor air distribution systems (UFAD): floor-supply displacement ventilation (FSDV), horizontal flow-type floor diffuser (HFD), and swirling flow-type floor diffuser (SFD). Two situations were considered: Case A, a consulting room, and Case B, a restaurant or meeting room. The difference in infection risk assessment between using CO2 and artificial saliva particles as tracers of exhaled breath was also discussed. Results indicate that the distribution of exhaled air and infection risk for doctors decreased in the order FSDV < HFD < SFD. Although the effect of introducing hoods was confirmed to a certain degree for the three ventilation methods in Case A, the effect of the hoods on the quanta concentration of the facing person was small in Case B. Comparing airborne infection risks between gas and particles, particle-based airborne infection was smaller in the FSDV due to the more significant impact of particle adhesion and falling. As a limitation, the ventilation rate in the experiment was 1000 m3/h (50 ACH). Therefore, the air supply method had a more significant impact on the results than the hood method. A practical implication of this experiment is that even under high ventilation volumes (50 ACH), the FSDV can reduce the horizontal distribution of the patient's exhaled air and prevent airborne infection. These results should be adapted to smaller spaces such as examination rooms and meeting rooms.

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Bigras, M. L.-S. C.-M.
Influenza aviaire H5N1–Recommandations pour la protection des travailleurs du secteur avicole.
INSPQ: Institut national de santé publique du Québec 2022

Cet avis vient moduler les recommandations effectuées dans le document Protection personnelle des travailleurs de l'industrie avicole dans le cadre de la surveillance et de la lutte contre l'influenza aviaire de 2006 et le remplace. Les recommandations intérimaires présentées sont basées sur les connaissances actuelles sur l'IAHP H5N1 présentement en circulation au Québec et l'information disponible au moment de rédiger ces recommandations. Puisque la situation et les connaissances sur le virus évoluent, les recommandations formulées dans ce document sont sujettes à modifications.

Les mesures de prévention et de protection présentées dans cet avis s'appliquent pour les milieux de travail où les travailleurs peuvent être en contact avec des oiseaux d'élevage, dans un contexte de surveillance et de présence confirmée d'IAHP sur le territoire québécois. Cet avis ne traite pas de la gestion des contacts avec des oiseaux infectés, des cas humains et leurs contacts ni des aspects de santé animale. Il s'adresse notamment aux équipes de santé au travail des directions de santé publique et aux milieux de travail concernés (ex. : élevage avicole, agronomie, livraison, service vétérinaire).

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Deprez, S. A.
Investigating the Effects of Airflow Adjustments and Room Layout on Aerosol Propagation in a University Classroom using CFD.
ASHRAE Transactions. 2024 ASHRAE Winter Conference - Chicago

In response to the SARS-CoV-2 pandemic, the HVAC industry has been committed to increasing focus on designing and installing systems that provide filtration and treatment of conditioned air efficiently and economically. However, there is limited research on how minor adjustments to room layout and HVAC system

operation may provide an economical way to improve the potential for reduced aerosol distribution throughout a room. This study hypothesized that strategic HVAC system operation and room layout adjustments can help mitigate the airborne spread of aerosols, including those that may contain a viral load. The intent of this study was to provide a quantitative process for informing decisions in HVAC operation and room layouts for reducing and mitigating aerosol spread from an instructor in a university classroom. This study used computational fluid dynamics (CFD) to construct, analyze, and assess several low- or no-cost alterations to predict the distribution of aerosols throughout the classroom. In doing so, it was determined that limiting localized airflow mixing near the aerosol source was advantageous, particularly in HVAC cooling operations. In addition, impeding the projection of aerosols from the source provided the most benefit in heating operations, advantageously using the reduced degrees of airflow mixing due to thermal stratification.

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Huzayyin, O., Zaki, A., Ali, S.
Investigating the impact of a window air conditioner with H-14 HEPA filter on lessening SARS-COV-2 aerosols.
Journal of Engineering and Applied Science, Vol. **71** n°(1), (2024)

This research breaks new ground by proposing a unique solution to combat SARS-COV-2 aerosols: modifying a readily available window air conditioner's indoor blower to accommodate a HEPA (high-efficiency particulate air) filter. While traditional public health measures like lockdowns and mask-wearing remain crucial, this study explores an innovative engineering approach to air purification within homes and offices. The widespread impact of COVID-19 across various sectors—agriculture, manufacturing, finance, and more—necessitates exploring diverse solutions. Current efforts to utilize HEPA filters in HVAC systems face limitations. These filters, while highly effective at capturing airborne particles, increasingly impede airflow and require substantial pressure, posing challenges for standard HVAC systems to maintain efficient operation. This study addresses this critical gap by proposing a targeted modification to a specific window air conditioner (AC) model (GJC07AF-K3RNB9D) to incorporate an H-14 HEPA filter. Utilizing cutting-edge design tool (CF-TURBO) and advanced simulation software (STARCCM +), the research will provide a new blower specifically optimized for this application. This virtual testing will meticulously evaluate the modified system's performance, ensure optimal airflow, predict noise levels, and identify any potential design flaws before implementing the modification in a physical prototype. The success of this study could pave the way for the development of increasingly efficient and accessible HEPA-based air purification solutions for everyday use, particularly in areas with limited resources. Furthermore, this research can be a valuable foundation for future work aimed to increasingly improve indoor air quality (IAQ).

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Leow, C. H., Saw, L. H., Low, F. S.
Investigations of the UVC 222 NM air cleaning system in an air-conditioned room.
Building and Environment, Vol. **265**, (2024)

Far-Ultraviolet-C (far-UVC) 222 nm was introduced during the Covid-19 pandemic to disinfect the airborne pathogens, particularly SARS-CoV-2. Although far-UVC 222 nm has shown promising results in surface disinfection, its efficacy in air disinfection remains uncertain due to additional variables in air. This study investigated the efficacy of far-UVC 222 nm UVGI in air disinfection experimentally, using total plate count, and input the measured far-UVC intensity into the computational fluid dynamic model to predict infection risk using the Wells-Riley model. Experimental results indicated that after 1 h of far-UVC irradiation, an equivalent far-UVC dosage of 21.31 J/m2, airborne bacteria concentration was reduced by 44.4 %–74.1 %, while airborne fungal concentration showed a marginal reduction. In a recirculating air-conditioned room, a 20 W far-UVC fixture installation, referred to as Case 1, demonstrated the highest available dosage of 7.66 % difference compared to Case 2. The use of far-UVC in Case 1 can reduce the risk of infection for the influenza H1N1,

SARS-CoV-2, and Mycobacterium tuberculosis by 54.48 %, 60.06 %, and 83.73 %, respectively. The study suggests installing far-UVC near the recirculating air-conditioner supply air jet and away from surrounding walls for optimum effectiveness. These results provide recommendations for alternatives to upper-room UVGI, offering a viable option for continuous room air and surface disinfection.

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Sandys, V., Simpson, A., Keen, C., Chen, Y.
Managing SARS-CoV-2 transmission risk in workplace COVID-19 outbreaks.
Annals of Work Exposures and Health, (2024)

A Coronavirus disease 2019 (COVID-19) workplace outbreak is a risk to the health of workers and business continuity. To minimise this risk, companies have implemented risk management measures (RMMs) designed to mitigate SARS-CoV-2 transmission within the workforce. The objective of this work was to gather insights into the application of RMMs in non-healthcare workplaces and to improve understanding of the practical barriers to their implementation.Data were collected using a pre-designed framework from 12 volunteer workplaces through discussions with staff responsible for site safety and during site visits to observe the RMMs and work processes. To evaluate ventilation effectiveness, measurements for carbon dioxide (CO2) were taken during the site visit and logged over an extended period in selected occupied areas.RMMs that were implemented well included working at home for office and other non-production staff, provision, and use of face coverings, provision for hand hygiene, and as methods became commonly available, carrying out testing for infected people. However, maintaining adequate physical distancing in many production areas proved difficult because established factory layouts cannot be easily changed and there is often a need for workers to be close to each other to communicate. A major shortcoming identified was the understanding and application of measures to improve workplace ventilation. Rapidly installing and/or upgrading mechanical ventilation systems during a pandemic may not be practical and ideally should be considered in building design. Measuring CO2 in occupied workspaces proved to be a useful tool for identifying areas with potentially inadequate ventilation.Preventing workplace attendance by identifying infected individuals is challenging, making effective RMMs crucial to mitigating virus transmission. The effectiveness of individual RMMs can be uncertain; therefore, it is necessary to adopt multilayered RMMs. Successful implementation relies on measures that are specific to individual workplaces, identified by accurate risk assessment, regularly reviewed for effectiveness, and worker compliance. Establishing suitable risk mitigation policies and providing staff supervision are vital to ensure the sustained and effective implementation of RMMs. For RMMs that require technical understanding, such as workplace ventilation systems, specialist support may be necessary to ensure effective implementation.

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Kooh, P., Guillois, Y., Federighi, M., Pivette, M., Maillard, A.-L., Luong, N.-D. M.*, et al.*
Mitigating COVID-19 in meat processing plants. What have we learned from cluster investigations?
Frontiers in Public Health, Vol. **12**, (2024)

Several COVID-19 outbreaks have been reported in meat processing plants in different countries. The aim of this study was to assess the environmental and socio-economic risk factors favouring the transmission of SARS-CoV-2 in meat processing plants and to describe the prevention measures implemented.Data from epidemiological investigations of COVID-19 clusters in France, the scientific literature, structured interviews and site visits were collected and summarised to investigate the main risk factors for SARS-CoV-2 infection in meat processing plants, including determinants within and outside the workplace.An increased risk of infection was identified among workers with unfavourable socio-economic status (temporary/non-permanent workers, migrants, ethnic minorities, etc.), possibly related to community activities (house-sharing, car-sharing, social activities). Working conditions (proximity between workers) and environmental factors (low temperatures and inadequate ventilation) also appear to be important risk factors. These environmental

conditions are particularly prevalent in cutting and boning plants, where the majority of reported cases are concentrated.Preventive measures applied included screening for COVID-19 symptoms, testing, wearing masks, increased hygiene and sanitation, physical and temporal distancing, control of ventilation. Certain food safety hygiene measures were compatible with protecting workers from SARS-CoV-2. The hygiene culture of agri-food workers made it easier to implement preventive measures after adaptation. This study made it possible to identify the environmental and socio-economic factors conducive to the transmission of SARS-CoV-2 in meat processing plants. The knowledge gained from this work was used in simulations to understand the transmission of the virus in the plants.

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Rahn, S. A.
Modeling and simulation of SARS-CoV-2 transmission in dynamic crowds.
TUM School of Computation, Information and Technology. Technical University of Munich. Thèse 2024

This work presents a modeling approach for the transmission of pathogens such as the coronavirus. A transmission model is integrated into agent-based crowd models, which permits the analysis of specific spreading events. The simulator is open-source. Reenacting superspreading events and predicting individual exposure risks for various scenarios using uncertainty quantification methods support the model's validity.

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King, M. D.
Monitoring airborne pathogen transmission for enhanced safety at food processing facilities.
Acta Alimentaria, (2024)

Food manufacturing and processing are part of the nation's critical infrastructure. Due to the recent global spread of the SARS-CoV-2 virus, the potential contamination of the food chain and the resulting public health implications are of high consequence to society. The current primary food manufacturing and processing facilities already have various mechanisms such as hazard analysis and critical control point (HACCP) system in place. However, the widespread microbial infections in these facilities raise concerns that they will not only threaten the welfare of food processing workers, but also have a potentially greater consequence on the public if the food is contaminated with an infectious agent.
Despite the increasingly recognised role of the environment in the spread of microbes, the effect of air properties remains poorly understood. Heating, ventilation, and air conditioning (HVAC) systems in meat processing facilities not only provide a means of transport for viruses and bacteria but may also deposit them on surfaces where they can survive for days. To maintain a stable and safe food chain supply during the pandemic, the challenges to ensure safe food supply and protect the workers' health must be quickly addressed through sustainable, safe and economic approaches. With these two imminent challenges in mind, the overall goal of this review article is to provide a comprehensive overview of the role of the environment in the impaction and resuspension of bioaerosols, focusing on airborne bacteria and viruses. The review includes the latest results of modeling the spread of microbial aerosols in the airflow and the development of preventive measures to mitigate virus contamination in the unique environment of meat processing operations. By understanding how the environmental factors and seasonality affect the infectivity and spread of airborne pathogens, mitigation measures can be designed to minimise future infections within and beyond these facilities.

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Gong, Z., Song, T., Hu, M., Che, Q., Guo, J., Zhang, H.*, et al.*
Natural and socio-environmental factors in the transmission of COVID-19: a comprehensive analysis of epidemiology and mechanisms.
BMC Public Health, Vol. **24** n°(1), (2024)

There are significant differences in the transmission rate and mortality rate of COVID-19 under environmental conditions such as seasons and climates. However, the impact of environmental factors on the role of the COVID-19 pandemic and the transmission mechanism of the SARS-CoV-2 is unclear. Therefore, a comprehensive understanding of the impact of environmental factors on COVID-19 can provide innovative insights for global epidemic prevention and control policies and COVID-19 related research. This review summarizes the evidence of the impact of different natural and social environmental factors on the transmission of COVID-19 through a comprehensive analysis of epidemiology and mechanism research. This will provide innovative inspiration for global epidemic prevention and control policies and provide reference for similar infectious diseases that may emerge in the future.

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Huang, W., Pan, Y., Zhou, Y., Chen, C.
Optimal location design for multiple Far-UVC lamps to enhance indoor bioaerosol disinfection by CFD-based Bayesian optimization.
Building and Environment, Vol. **264**, (2024)

In occupied indoor environments, 222 nm far-UVC is a secure and effective approach for controlling the spread of infectious bioaerosols. To enhance the disinfection effectiveness, it is crucial to carefully design the placement of far-UVC lamps, by considering the impact of airflow pattern, bioaerosol distribution, and irradiance exposure. Using CFD alone for designing the locations of multiple lamps presents challenges due to the high computational cost resulting from the high number of potential combinations. Therefore, this study combined CFD with the Bayesian optimization method to improve the computational efficiency, enabling customized design for complex scenarios. The proposed method was first validated with experimental data and the results from the grid search method. Next, the validated method was applied to design the placement of multiple far-UVC lamps in a railway compartment. In the studied railway compartment, just 1 h of optimization led to 1.05-fold–2.87-fold improvement in bioaerosol disinfection efficiency compared to random selection and uniform distribution. This optimization method for customized location design can maximize the utilization of far-UVC lamps, reducing equipment investment and energy consumption while ensuring effective disinfection.

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Lu, K., Ding, Z., Qian, H., Zheng, X.
Positive or negative? The pressure control impact in hybrid ventilated hospitals.
Indoor and Built Environment, (2024)

The outbreak of coronavirus disease 2019 (COVID-19) has had a significant impact on human life. Hybrid ventilated hospitals have emerged as multi-zone sites, necessitating ventilation strategies to mitigate viral concentration. This paper integrates multi-zone infiltration and exfiltration (MIX) model of natural ventilation, spatial flow impact factor (SFIF) model and pollutant concentration model to analyze the inter-zonal impact. Results indicate that elevated outdoor temperature corresponds to an increased influence of rooms on corridors. Adopting mechanical ventilation in rooms diminishes the influence of room pollutants on corridors but exerts minimal impact on other rooms. Mechanical air supply reduces the interaction between corridors, and the reduction is most significant when wind direction is the same as stairwell orientation. The corridors do not affect the upstream rooms when the source is in the corridor. When wind speed is below a threshold, mechanical air supply is recommended; for wind speed reaching this threshold, mechanical air exhaust volumes should be adjusted regarding the wind speed. The study reveals that corridor and room window openings exert disparate effects on corridor concentration under mechanical air supply conditions. All the findings offer valuable insights for selecting ventilation strategies in hybrid ventilated hospitals, with the aim of mitigating COVID-19 transmission.

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Mukai, Y., Sadakane, T., Toyota, Y., Kato, T., Koh, I., Saeki, N.*, et al.*
Prevention of COVID-19 infection in the delivery room by assessing smoke test visualization of exhaled air.
Hiroshima J Med Sci, Vol. **73** n°(1-2), (2024), 15-21 p.

The principal route of the coronavirus disease 2019 (COVID-19) infection is through the inhalation of respiratory droplets and aerosols. To date, there are no reports on the control of aerosol-mediated infections during vaginal delivery. This study aimed to visualize the airflow in a delivery room and use this information to develop infection control measures. A tracheal intubation practice manikin was used for the experiment. Smoke was generated using fog liquid and a fog machine. Smoke was collected in a plastic bag connected to the lower pharynx of the manikin via a conduit. Exhaled airflow was visualized by irradiating exhaled smoke with a laser beam. We visualized the aerosol flow from the mouth and nose of the manikin by compressing a plastic bag filled with smoke. We performed a smoke test to check the expiratory flow and accordingly modified the delivery room in two ways: the head side of the delivery table was surrounded with a plastic sheet, and the exhaust pipe was passed through the vinyl sheet to the exhaust port. After these modifications, we managed 18 vaginal deliveries in parturient women with COVID-19, with no related infections among the babies or staff. With emerging infectious diseases, such as COVID-19, the route of infection may be unclear and determining appropriate infection control measures can be difficult. By considering the characteristics of the virus and implementing appropriate infection control measures, we can safely manage high-risk vaginal deliveries.

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Rasam, H., Gentile, V. M., Tronville, P., Simonetti, M.
Reducing direct exposure to exhaled aerosol through a portable desktop fan.
Atmospheric Environment-X, Vol. **22**, (2024)

Vulnerable individuals close to infected people emitting a respiratory cloud containing infectious load can inhale a pathogen dose, experiencing a more severe impact on their health compared to other individuals breathing the mixed air in the same room. In crowded spaces, this issue is crucial. Employing local airflow patterns can reduce the proximity risk of inhalation and subsequent transmission across short distances. This study proposes an experimental and numerical analysis of a novel personal and portable device creating a short-range air barrier to transmitting airborne pathogens in proximity. The portable device adopts V-shaped air blades affecting the trajectory of the particle -laden respiratory cloud emitted by the respiratory system of the infected individual. Experimental results, supported by CFD analysis, indicate that controlling local airflow through the V-shaped jet significantly reduces local particle concentrations by more than 60%, compared to typical scenarios without a local airflow control.

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Moseley, B., Archer, J., Orton, C. M., Symons, H. E., Watson, N. A., Saccente-Kennedy, B.*, et al.*
Relationship between Exhaled Aerosol and Carbon Dioxide Emission Across Respiratory Activities.
Environmental Science & Technology, Vol. **58** n°(34), (2024), 15120-15126 p.

Respiratory particles produced during vocalized and nonvocalized activities such as breathing, speaking, and singing serve as a major route for respiratory pathogen transmission. This work reports concomitant measurements of exhaled carbon dioxide volume (VCO2) and minute ventilation (VE), along with exhaled respiratory particles during breathing, exercising, speaking, and singing. Exhaled CO2 and VE measured across healthy adult participants follow a similar trend to particle number concentration during the nonvocalized exercise activities (breathing at rest, vigorous exercise, and very vigorous exercise). Exhaled CO2 is strongly correlated with mean particle number (r = 0.81) and mass (r = 0.84) emission rates for the nonvocalized

exercise activities. However, exhaled CO2 is poorly correlated with mean particle number (r = 0.34) and mass (r = 0.12) emission rates during activities requiring vocalization. These results demonstrate that in most real-world environments vocalization loudness is the main factor controlling respiratory particle emission and exhaled CO2 is a poor surrogate measure for estimating particle emission during vocalization. Although measurements of indoor CO2 concentrations provide valuable information about room ventilation, such measurements are poor indicators of respiratory particle concentrations and may significantly underestimate respiratory particle concentrations and disease transmission risk.

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Batista Ferreira, W., Batista Chaves Azevedo De Souza, M., Aparecida Alves Da Silva, C., Emmilly Guedes Da Silva, J., Cristina De Oliveira E Silva, A., Maria Do Carmo Alonso, C.*, et al.*
Reported risk factors for COVID-19 infection in healthcare workers: A systematic review: COVID-19 infection in healthcare workers: A systematic review.
Safety Science, Vol. **178**, (2024)

This review aimed to raise and systematize how the literature reports the categories of health professionals who became ill working during the first fourteen months of the pandemic, as well as critically analyze the risk factors related to COVID-19 contamination. The principles established by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis were applied and studies published in English, Spanish and Portuguese since 2019 in four databases. The Boolean descriptors and operators used were: 'Healthcare professional' AND 'COVID-19' OR 'SARS-CoV-2' AND 'Risk factors' AND 'Incidence' AND 'Prevalence'. Zotero® software was used for data processing. 4,632 articles were selected for reading the titles, of which 3,429 were excluded. After inclusion and exclusion criteria, 20 articles were selected to review. The results showed the presence of risk factors in workers in various sectors of health services, who were facing the pandemic, showing that the increase in the occurrence of diseases among workers was related to the shortage of personal protective equipment, the misuse or inappropriate use of these devices and insufficient training to deal with the virus. In summary, this review shows that there is still a need to guarantee and implement health policies.

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Li, J., Zuraimi, S., Schiavon, S.
Should we use ceiling fans indoors to reduce the risk of transmission of infectious aerosols?
Indoor Environments, Vol. **1** n°(3), (2024)

The effects of ceiling fans on the transmission of infectious aerosols remain poorly understood, leading to conflicting recommendations. We conducted repeated experiments in a well-controlled chamber with a typical mixing ventilation system at three different ventilation rates with and without ceiling fans. We evaluated airborne infection risks for short- and long-range transmission routes based on size-resolved tracer particles measured at various locations. We found that the mixing ventilation without fans only effectively diluted the airborne particle concentration for the long-range route but not for the short-range. By using ceiling fans to enhance air mixing, tracer particles were distributed more homogeneously throughout the room, leading to up to 77 % reduction in short-range particle exposure while a slight increase of less than 14 % in long-range exposure. Based on the dilution-based Wells-Riley model, the changes in particle concentration translated to a maximum 47 % reduction in short-range infection risk and a marginal 4 % increase for long-range transmission. Based on the dilution factors obtained from the experiments, we developed a decision-making tool that uses the ventilation rate, the number of individuals at short- and long-range, and the disease's transmissibility to decide whether the use of ceiling fans is beneficial. Deploying ceiling fans always reduces the concentration of particles in the short range and, assuming a relationship between particles and pathogens, this directly translates to a diminished short-range risk. Based on the modeling of the overall risk, the benefits of fans are highest when the room is ventilated according to code, when masking measures are in place, and when the pathogen is not highly contagious.

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Albertini, R., Colucci, M. E., Viani, I., Capobianco, E., Serpentino, M., Coluccia, A.*, et al.*
Study on the Effectiveness of a Copper Electrostatic Filtration System "Aerok 1.0" for Air Disinfection.
Preprints, (2024)

Background: Bioaerosol can represent a danger to the health. During SARS-CoV-2 pandemic, portable devices were used in different environments and considered a valuable prevention tool. This study has evaluated the effectiveness of the air treatment device “AEROK 1.0” in reducing microbial, particulate and pollen airborne contamination indoors, during normal activity. Methods: In an administrative room, airborne microbial contamination was measured using active (DUOSAS 360 and MD8) and passive sampling; a particle counter was used to evaluate particle concentrations; a Hirst-type pollen trap was used to assess airborne pollen and Alternaria spores. Statistical analysis was performed using SPSS 26.0; p values <0.05 were considered statistically significant. Results: The airborne bacterial contamination assessed by the two different samplers decreased by 55.54% and 69.13%, respectively. The airborne bacterial contamination assessed by passive sampling decreased by 44.16%. For fungi, the reduction was 38.7% by active sampling. Airborne particles (diameters ≥ 1.0, 2.0 µm) and the ratio of indoor/outdoor concentrations of total pollen and Alternaria spp spores significantly decreased. Conclusions: The results highlight the effectiveness of AEROK 1.0 in reducing airborne contamination. The approach carried out represents a contribution to the definition of a standardized model for evaluating the effectiveness of this type of devices.

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Hayashi, M., Honma, Y., Kikuta, K., Hasegawa, A., Murata, S., Yamada, H.*, et al.*
Ventilation measures to control aerosol transmission based on COVID-19 outbreaks in hospitals in Japan.
Japan Architectural Review, Vol. **7** n°(1), (2024)

COVID-19 outbreaks occurred in several hospitals, and the National Institute of Infectious Diseases, local authorities, and universities carried out investigations into ventilation in hospitals. The results indicated that ventilation performance was insufficient to prevent aerosol infection due to poor air conditioning, equipment maintenance, and existing ventilation design guidelines. The authors investigated guidelines for ventilation measures for general patient wards with the cooperation of The Society of Air-Conditioning and Sanitary Engineers of Japan and the Japanese Society for Infection Prevention and Control. Based on a survey of COVID-19 outbreaks in hospitals, ventilation countermeasure plans for 3 stages (a. normal conditions, b. increased risk of outbreaks, and c. infected patients treated) were compiled.

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Du, C., Chen, J., Mccarty, D., Chen, Q.
Ventilation performance of induction displacement units in indoor spaces within cold regions.
Sustainable Cities and Society, Vol. **114**, (2024)

Efficient ventilation systems play a crucial role in reducing occupants' exposure to indoor contaminants, including particles potentially carrying viruses like SARS-CoV-2. Displacement ventilation systems have demonstrated their effectiveness in improving indoor air quality during cooling modes. However, traditional displacement ventilation systems often struggle to achieve satisfactory distribution of contaminant concentrations during heating modes. To address this issue, this study focused on enhancing the ventilation performance of a dual-coil displacement-induction unit. Through a combination of experimental measurements and computational fluid dynamic (CFD) techniques, the study examined airflow and contaminant concentration distributions in an environmental chamber conditioned by these units. The results demonstrated good agreement between measured and simulated data, validating the CFD model. Further evaluation in a 25-occupant classroom under cold outdoor conditions showed that the dual-coil unit could

achieve satisfactory ventilation performance in heating modes with proper design, comparable to traditional displacement ventilation in cooling modes. Additionally, the unit's versatility allows it to accommodate a wide range of air conditioning applications, from heating to cooling, making it a promising solution for displacement ventilation in various environments.

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Mahdood, B., Merajikhah, A., Mirzaiee, M., Bastami, M., Banoueizadeh, S.
Virus and viral components transmitted through surgical smoke; a silent danger in operating room: a systematic review.
BMC Surg, Vol. **24** n°(1), (2024)

During surgical procedures, heat-generating devices are widely used producing surgical smoke (SS). Since the SS can transmit infectious viruses, this systematic review was designed to investigate the potential viruses transmitted through SS.MethodsPubMed, Scopus, Web of Science, ProQuest, and Embase databases, along with Cochran Library, and Google Scholar search engine were searched systematically (by April 21, 2024). No language, place, and time restrictions were considered. All studies evaluating the SS and virus transmission, and whole investigations regarding the viral infections transmitted through SS were totally considered inclusion criteria. Besides, non-original, qualitative, case reports, case series, letters to the editor, editorial, and review studies were excluded from the analysis. This study was conducted in accordance with the PRISMA 2020 statement.ResultsTwenty-six eligible studies were selected and reviewed for data extraction. The results showed that the SS contains virus and associated components. Six types of viruses or viral components were identified in SS including papillomavirus (HPV, BPV), Human Immunodeficiency Virus (HIV), varicella zoster, Hepatitis B (HBV), SARS-CoV-2, and Oral poliovirus (OPV), which are spread to surgical team through smoke-producing devices.ConclusionsSince the studies confirm the presence of viruses, and viral components in SS, the potential risk to the healthcare workers, especially in operating room (OR), seems possible. Thus, the adoption of protective strategies against SS is critical. Despite the use of personal protective equipment (PPE), these viruses could affect OR personnel in surgical procedures.

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