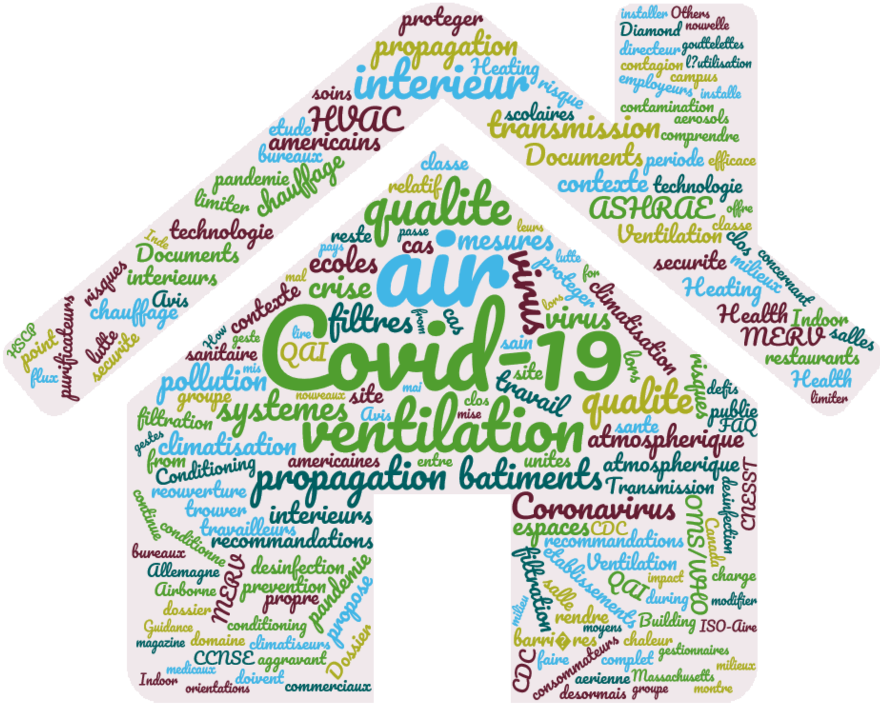

Bulletin de veille AéroCovid
N°124 – 29/10/2025

Objectif : *Air intérieur, ventilation, climatisation et propagation du Covid-19*

La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS. Les éléments issus de cette veille sont founis sans garantie d'exhaustivité.

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Google Scholar, Lens et WoS

Roberts, B. M., Adzic, F., Hamilton-Smith, A., Iddon, C., Wild, O., Cook, M., *et al.*

[Air quality at mass gatherings: assessing ventilation and occupancy in marquees to evaluate airborne infection risk during the COVID-19 pandemic.]

Building and Environment, Vol. **287**, (2026)

The COVID-19 pandemic led to the cancellation of mass gathering events to slow the transmission of the SARS-CoV-2 virus, partially due to evidence that the virus can spread via airborne routes, especially in densely occupied, poorly ventilated spaces. Structures such as marquees (large tents), are commonly used at mass gathering events and were a frequently designated “outdoor safe space” during the COVID-19 pandemic. There is, however, scant evidence as to whether semi-outdoor buildings are sufficiently ventilated relative to the occupancy levels to reduce airborne transmission. As part of the largest study of mass gathering events to date, we measured ventilation and occupancy at 80 real events. We compared seven semi-outdoor spaces and one indoor space. Our results showed that most semi-outdoor buildings were sufficiently ventilated relative to the occupancy (mean CO2 <800 ppm). Short peaks in CO2 concentration of up to 1200 ppm indicated intermittent, but brief, periods of insufficient ventilation relative to the occupancy in some spaces. High occupant density, heterogeneous occupant distribution (crowding), and poor ventilation management strategies negatively influenced the indoor air quality. Event management strategies, such as intervals between events, improved air quality. We conclude that semi-outdoor buildings are not inherently low-risk with respect to long-range airborne pathogen transmission and so require careful consideration for the ventilation provision relative to the occupancy. The evidence presented, using the largest field study of its kind worldwide, provides key evidence to inform revisions to building regulations and pandemic preparedness plans concerning the use of semi-outdoor buildings.

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Sadeghi, S., Aminossadati, S. M., Leonardi, C.

A Critical Review of Critical Factors Influencing Airborne Particle Transmission in Indoor Environments Under Stationary and Dynamic Scenarios.

Archives of Computational Methods in Engineering, (2025)

Understanding the spread of airborne viruses in indoor environments is a complex challenge due to the interplay of physical, environmental, and chemical factors. While numerous studies have specified elements such as human movement, ventilation strategies, relative humidity, air pollutants, particle size, and exhalation velocity individually, there is a notable lack of comprehensive reviews that integrate these factors, particularly in dynamic indoor scenarios. This paper provides a thorough review and categorization of key factors influencing respiratory particle behavior, with a particular focus on how human movement alters airflow patterns, turbulence, and viral particle trajectories. This review also examines how mobility-induced wake flow, particle resuspension, and enhanced pathogen dissemination impact viral transmission. Research gaps in the current literature are identified and some recommendations for future research are provided to improve modeling techniques for respiratory particle behavior and enhance indoor air quality control strategies. Based on the findings, aerosols are a significant contributor to transmission risk, accounting for 23.1%, with particles smaller than 5–10 µm being up to 100 times more infectious than larger particles. Effective ventilation strategies, especially displacement ventilation, are crucial in mitigating these risks. Additionally, environmental conditions such as temperatures between 20 and 25 °C and relative humidity levels of 40–60% can help deactivate viruses. According to the studies, human movement is a major factor, increasing cumulative air and aerosol exchange by approximately 33% compared to static conditions, with walking speed significantly affecting droplet persistence and airflow disruptions.

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Sadeghi, S., Aminossadati, S. M., Leonardi, C.

A Critical Review of Critical Factors Influencing Airborne Particle Transmission in Indoor Environments Under Stationary and Dynamic Scenarios.

2025 World Skills Conference on Universal Data Analytics and Sciences (WorldSUAS)

Understanding the spread of airborne viruses in indoor environments is a complex challenge due to the interplay of physical, environmental, and chemical factors. While numerous studies have specified elements such as human movement, ventilation strategies, relative humidity, air pollutants, particle size, and exhalation velocity individually, there is a notable lack of comprehensive reviews that integrate these factors, particularly in dynamic indoor scenarios. This paper provides a thorough review and categorization of key factors influencing respiratory particle behavior, with a particular focus on how human movement alters airflow patterns, turbulence, and viral particle trajectories. This review also examines how mobility-induced wake flow, particle resuspension, and enhanced pathogen dissemination impact viral transmission. Research gaps in the current literature are identified and some recommendations for future research are provided to improve modeling techniques for respiratory particle behavior and enhance indoor air quality control strategies. Based on the findings, aerosols are a significant contributor to transmission risk, accounting for 23.1%, with particles smaller than 5–10 µm being up to 100 times more infectious than larger particles. Effective ventilation strategies, especially displacement ventilation, are crucial in mitigating these risks. Additionally, environmental conditions such as temperatures between 20 and 25 °C and relative humidity levels of 40–60% can help deactivate viruses. According to the studies, human movement is a major factor, increasing cumulative air and aerosol exchange by approximately 33% compared to static conditions, with walking speed significantly affecting droplet persistence and airflow disruptions.

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Barakat, M. T., Lee, L. D., Conti, N., Angelotti, T.

Endoscopy Unit Implementation of a Sealed In-Room Air Purifier with Ultraviolet Irradiation Reduces Bacterial and Airborne Particle Levels.

Dig Dis Sci, (2025)

There is a need for enhanced air quality in healthcare settings, particularly in areas with high levels of airborne particles and complex room layouts. This study evaluated the impact of germicidal ultraviolet air purification devices (GUVAPD) on bacterial contamination and airborne particle levels in endoscopic procedural rooms.

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Sharma, A., Sharma, A.

Fuzzy Logic-Based Prediction of Probability of Infection in Mahakal Ujjain Temple, India: Enhancing Ventilation Strategies for Public Health Safety.

National Academy Science Letters, (2025)

In densely populated religious sites like Mahakal Ujjain Temple, maintaining indoor air quality is vital for health safety. This study applies fuzzy logic to predict the probability of airborne infection using variables such as ACH, population density, temperature difference, physical activity, and respiratory activity. Fuzzy sets manage real-world uncertainty, while a rule-based fuzzy inference system evaluates infection risk. Model validation shows strong correlation ($R2 = 0.823$) between predicted and actual values, confirming its reliability in guiding ventilation strategies.

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Rey, J. F., Hager Jörin, C., Cesari, M., Favreau, P., Pasquettaz, R., Perret, V., *et al.*

Influences of season, ventilation, SARS-CoV-2 pandemic protective measures, and energy-shortage on VOC levels in Western Switzerland's primary schools.

Indoor Environments, Vol. **2** n°(4), (2025)

Indoor air pollution is a major threat to human health, contributing to both acute and chronic diseases in exposed individuals. School environments are particularly at risk, as they host vulnerable populations which spend a considerable amount of time indoors. Among the myriad pollutants found in indoor settings, volatile organic compounds (VOCs) are especially common and some of them have been associated with health effects from irritation to cancer following prolonged exposure. In this study, we assessed the presence of VOCs in 24 primary schools in the canton of Fribourg, Switzerland. VOCs were passively sampled at each school in three locations (twice indoors and once outdoors) for four one-week campaigns conducted across different seasons. These campaigns also captured variations due to SARS-CoV-2 protective measures and energy-saving restrictions. Overall, indoor air quality was found to be good in most of the monitored classrooms. However, elevated levels of alcohol (ethanol and isopropanol), reaching up to 40,000 µg/m3, were observed in classrooms during the enforcement of pandemic-related protective measures. Mechanical ventilation systems were associated with a general reduction in VOC exposure. Regarding indoor air reference values, most of the regulated compounds were in line with Switzerland's or neighboring countries' guidelines. This study demonstrates that although VOC concentrations generally remain low and within recommended limits, their consistent presence indicates numerous potential sources of exposure for both children and teachers, who spend extended periods in these environments.

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Rodríguez, D., Jiménez, E., Quiles, R., Acosta, I., Bustamante, P., Campano-Laborda, M. Á.

Integral analysis of indoor environmental quality in a hemodialysis unit: Indoor air quality and airborne diseases relative risk.

Building and Environment, Vol. **286**, (2025)

Monitoring indoor environmental quality (IEQ) is essential in healthcare facilities, particularly in hemodialysis (HD) units where vulnerable patients remain for 4–5 h per session several times per week. This study conducted an integrated assessment of hygrothermal comfort, indoor air quality (IAQ), and airborne infection risk in an HD unit under two scenarios: natural ventilation and controlled mechanical ventilation (CMV). IAQ was evaluated through CO2, benzene, formaldehyde, ozone, and particulate matter (PM0.3, PM2.5, PM10), while hygrothermal comfort was monitored via air temperature and humidity, Relative infection risk was estimated using CO_2-based modeling adapted from the Wells–Riley approach. Results showed that CMV maintained CO_2 below 800 ppm, meeting Spanish regulatory standards, whereas natural ventilation was insufficient despite high envelope permeability. PM2.5 and PM10 remained within WHO guidelines, but peaks of PM0.3 were observed, emphasizing the need for finer particle control. Infection risk was strongly influenced by activity level and mask use, with healthcare workers posing greater risk than patients. Deficient filter maintenance compromised pollutant removal, occasionally increasing PM during CMV operation. These findings highlight the necessity of optimized and well-maintained ventilation systems to balance air quality, comfort, and infection control in HD environments, offering methodological insights extendable to other healthcare settings.

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Jia, W., Cheng, P., Fontana, L., Chan, P. W., Wargocki, P., Li, Y.

Interpreting CO2 Monitoring for Assessing Airborne Transmission Risk in Indoor Environments.

Journal of Hazardous Materials, (2025)

Carbon dioxide (CO2) monitoring has been used for over a century to indicate indoor air quality, and in recent decades to measure ventilation. However, its use for indicating airborne infection risk remains controversial. CO2 is emitted by everyone and removed almost solely by ventilation, whereas virus-containing aerosols are emitted only by infectors and removed by other additional mechanisms. Accordingly, methods for interpreting CO2 monitoring data should be developed, and suitable conditions for its use need to be clarified. We propose two CO2-based surrogates, derived from monitored CO2 concentrations, to better interpret airborne infection risk. The first, per-person dilution (pCO2), mirrors CO2's emission rate but adopts the removal dynamics of infectious aerosols. The second, room dilution (rCO2), shares pCO2's removal rate but is emitted solely by infected individuals. We define scaling coefficients to estimate these surrogates and compare their temporal profiles with CO2 concentration excess to assess the impacts of occupant density, ventilation, and non-ventilation removal mechanisms. Using a year-long dataset from two indoor environments, we demonstrate how pCO2 and rCO2 effectively indicate steady-state and transient dilution ability, respectively. These surrogates provide a framework for interpreting CO2 data to assess airborne infection risk under specific conditions.

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Onkangi, R., Kuga, K., Ito, K.

[Is exhaled carbon dioxide an appropriate tracer for assessing airborne transmission risk?]

Building and Environment, Vol. **285**, (2025)

Understanding the inhalation exposure to exhaled carbon dioxide (CO2) and respiratory droplets in close-contact interactions is critical for assessing airborne infection risks in indoor environments. This study presents a numerical analysis comparing the spatiotemporal transport and inhalation of exhaled CO2 (modeled as a passive scalar) and virus-laden droplets (modeled using a Lagrangian discrete phase model) under various interpersonal distances, body postures, and respiratory activities (namely speaking and coughing). The results showed that although fine droplets (<5 μm) exhibit similar dispersion patterns to CO2 owing to their aerodynamic behavior, larger droplets deviate significantly because of gravitational and inertial forces. The arrival time and inhalation amount of CO2 were often earlier and higher, respectively, than those of the droplets, particularly in speaking scenarios. However, in coughing cases, the rapid dilution of the exhaled CO2 jet led to an underestimation of droplet exposure. Furthermore, exhaled CO2 did not account for dermal and nasal deposition, particularly for larger droplets. These findings highlight that CO2 can serve as a useful tracer for visualizing airflow and aerosol-like behavior but not as a reliable proxy for droplet transmission risk. Collectively, accurate risk assessment requires the integration of particle-specific dynamics, evaporation, and realistic emission profiles.

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Polus, M., Mucha, Z.

[Microbiological quality of atmospheric air at sewage treatment plants operating with different treatment technologies.]

Desalination and Water Treatment, Vol. **324**, (2025)

This article presents a study of bioaerosol emissions in a constructed wetland treatment plant with all technical facilities located outdoors compared to emissions from four other treatment plants using different technologies. Air analysis was performed based on microbiological indicators using culture methods. The concentration of bacteria determined at the aeration pond did not exceed 60cfu/m3 and was comparable to the boundary of the treatment plant's protection zone on both the windward (66cfu/m3) and leeward (60cfu/m3) sides. Measurements of the remaining microbiological indicators did not indicate a significant impact of the plant on the ambient air. A comparison of the constructed wetland with four treatment plants with partially enclosed process rooms showed that the operation of activated sludge bioreactors is a source of significantly higher microbial concentrations (up to 284 cfu/m³), and particularly high concentrations of bioaerosols are generated during the operation of the sludge dewatering centrifuges (up to 9460cfu/m³). The study showed that bioaerosol emissions from the constructed wetland did not exceed the permissible values for air without microbiological contamination. The obtained results indicate that the constructed wetland treatment plant does not pose a significant microbiological threat to the personnel or the immediate surroundings of the treatment plant.

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Rossi, F., Pelletier, K. P., Veillette, M., Paquet-Bolduc, B., Duchaine, C.

The Omicron variant significantly increases viral load emissions in healthcare settings: implication for healthcare workers.

Journal of Hospital Infection, Vol. **163**, (2025), 88-97 p.

Summary Background The SARS-CoV-2 Omicron variant is transmitted via contaminated droplets and aerosols, raising concerns in healthcare settings where poor ventilation and high patient density can increase airborne viral load. Aim This study aimed to assess real-world exposure of healthcare workers to COVID-19-positive patients isolated in designated hospital areas, using continuous 24-h air sampling. Methods Air sampling was conducted inside 10 hospital rooms hosting a succession of 38 patients who tested positive for SARS-CoV-2. Sampling was performed using 37-mm cassettes placed near the patients' heads. The Omicron variant in the air was detected by RT-qPCR, with results expressed as emission rates based on air changes per hour for each room and correlated with the onset of patients' symptoms. Findings The SARS-CoV-2 was detected and quantified in the air of 89% of patients, indicating that 76.7% of the rooms hosting positive patients had detectable levels of airborne virus. This corresponded to an average viral emission rate of 1.45 × 105 ± 2.16 × 105 genomes/h per patient. Expectoration was the sole symptom significantly affecting emission rates, with patient suffering from it exhibiting values three times higher than patients without. Additionally, the room accounted for half of the variance in emission rates, suggesting that the number of patients and the room's prior usage are key determinants of viral particle exposure. Conclusion Our findings indicate that healthcare workers face significant exposure when providing care in rooms with positive patients, even when mechanically ventilated. Greater attention should be given to treating and managing these spaces to reduce the potential for viral transmission toward healthcare workers.

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He, J., Liang, Q., Zhang, S., Yu, M., Xu, H., Cao, M., *et al.*

Quantitative evaluation of temperature and relative humidity effects on 222 nm UVGI air disinfection in a novel wind tunnel system.

Journal of Building Engineering, Vol. **114**, (2025)

Airborne transmission is a significant pathway for pathogen spread, making air disinfection crucial for preventing infectious diseases. Ultraviolet Germicidal Irradiation (UVGI) is widely recognized for air disinfection, and 222 nm UVGI has recently been shown to be safe for human exposure, making it a promising technology. However, the impact of temperature and relative humidity (RH) on 222 nm UVGI's efficacy remains underexplored. This study used a novel wind tunnel testing system and multi-point sampling to examine the effects of temperature and RH on 222 nm UVGI performance, comparing it to traditional 254 nm UVGI. The results revealed that temperature has minimal impact on disinfection efficacy, while RH significantly reduces its effectiveness. At 23 °C, the inactivation rate constants for Serratia marcescens were 35.60 cm2/mJ at 30 % RH and 36.81 cm2/mJ at 43 % RH. However, at 55 % and 68 % RH, these values dropped significantly to 9.03 cm2/mJ and 0.00 cm2/mJ, respectively. Furthermore, 222 nm UVGI outperformed 254 nm UVGI in disinfection efficacy. At 23 °C and 30 % RH, the inactivation rate constant for 254 nm UVGI was 15.00 cm2/mJ, much lower than the 35.60 cm2/mJ for 222 nm UVGI. These findings underscore the importance of temperature and RH in optimizing UV-based air disinfection.

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Liu, M., Liu, X., Jiang, X., Quan, L., Zhang, R., Lu, X., *et al.*

Real-time direct measurement of indoor respiratory aerosols.

Building and Environment, Vol. **287**, (2026)

Respiratory aerosols play a critical role in the airborne transmission of infectious respiratory diseases. Understanding the concentration of respiratory aerosols in indoor environments is a key for assessing the transmission risks of these diseases. Due to their extremely low number concentration, no method currently exists to distinguish and count respiratory aerosols when they are mixing with other indoor aerosols that are at least 1,000 times more abundant. Conventional approaches, such as computational fluid dynamics models and CO2 monitoring, while useful for estimating respiratory aerosol concentrations, have significant limitations as indirect methods. Here we introduce an online technique to directly detect and quantify respiratory aerosol concentrations based on single particle aerosol mass spectrometry (SPAMS) measurement. We discovered distinct SPAMS ion tracers (e.g., NaClCN− and NaClCNO−) specific to respiratory aerosols and validated their effectiveness in identifying respiratory aerosols from other indoor aerosol types. Applied in a real-world meeting, the method revealed rapid increases in respiratory aerosols during vocalization and their decline after occupancy. These results indicate that direct, real-time measurement of respiratory aerosols can add more specific evidence for assessing airborne transmission risk in indoor environments.

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Gong, Y., Shi, G., Zhu, J., Tang, S., Liu, H., Hu, S., *et al.*

Sparse sensor measurement for indoor physical field reconstruction with physics-inspired K-means and Kolmogorov-Arnold networks.

Journal of Building Engineering, Vol. **113**, (2025)

The COVID-19 pandemic has highlighted the critical importance of maintaining healthy indoor environments, particularly in air-conditioned spaces where airflow dynamics strongly affect thermal comfort and air quality. Accurate prediction and optimization of indoor air quality and thermal comfort are essential for mitigating airborne disease transmission and improving occupant well-being. Traditional measurement methods for velocity and temperature fields, however, are costly, difficult to scale, and yield sparse data. Numerical simulations, though useful, remain computationally expensive and highly sensitive to boundary conditions, limiting practical applicability. To address these challenges, we propose a novel artificial intelligence–integrated framework that combines sparse sensor measurements, physical priors, and advanced AI models. Our method introduces a physics-inspired K-means clustering algorithm for optimized sensor placement and employs Kolmogorov–Arnold Networks (KAN) to reconstruct indoor physical fields with high accuracy. By embedding physical knowledge into data-driven models, our approach achieves superior accuracy and robustness across diverse scenarios. In three-dimensional field reconstruction, it outperforms the second-best method by an average of 29% in MSE and 14% in MAPE. Comparative analyses and case studies further demonstrate the effectiveness of the proposed framework in Predicted Mean Vote (PMV) estimation and sensor layout optimization. Overall, this work presents a cost-effective and scalable solution for enhancing indoor environmental quality, offering both theoretical advances and practical benefits for building design and operation.

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