

Bulletin de veille QAI
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Objectif : *Air intérieur, ventilation, climatisation et propagation du Covid-19*

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Google Scholar, Lens et WoS

Siddique, M. A., Lopes, A. J.

Adaptive baseline-state compensation of low-cost PM2.5 sensors for continuous indoor environmental monitoring.

Results in Engineering, Vol. **32**, (2026)

Low-cost optical $PM_{2.5}$ sensors enable dense and continuous indoor air-quality monitoring in smart buildings, but sustained operation is affected by measurement noise, environmental influences, and slowly varying baseline-state behavior. This paper presents an adaptive sensing framework combining Savitzky–Golay signal processing, Allan deviation-based noise characterization, stochastic sensor modeling, Kalman filtering, and reinforcement learning to improve baseline-state estimation reliability during continuous indoor deployment. Process and measurement-noise parameters are derived directly from operational sensor data, enabling stochastic model parameterization and offline policy training without manual Kalman parameter selection. Analysis of a 15.62-day indoor dataset reveals a repeatable diurnal baseline-state oscillation; a four-channel model incorporating pressure, temperature, relative humidity, and gas resistance explains 88.0% of the variance in the hourly baseline-state profile. Under a 20-run synthetic Monte Carlo validation protocol, the learned Q-learning controller reduces RMS baseline-state error by 59.9%, achieving statistically comparable accuracy to a hysteresis controller (Wilcoxon $p = 0.261$); its principal advantage is automated intervention through offline training rather than manually specified thresholds. Evaluation on the held-out trajectory identifies a simulation-to-real discrepancy arising from structured temporal behavior not represented by the current stochastic model. The complete framework is deployed on a Raspberry Pi 5 with decision latency below 2 ms; an independent 5.98-day hardware deployment demonstrates real-time execution of the sensing, estimation, and supervisory-control pipeline without cloud computation. The results demonstrate the potential of this framework to support adaptive baseline-state management of low-cost $PM_{2.5}$ sensors in continuous indoor deployments.

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Carnec, N., Ferrand, M., Duforestel, T., Wall-Ribot, B., Abadie, M., Limam, K.

Adjoint-based corrective approach for nodal indoor air quality predictions.

Indoor Environments, Vol. **3** n°(4), (2026)

Indoor Air Quality (IAQ) modelling in building simulations often relies on the nodal approach to evaluate exposure to airborne pollutants. This approach assumes perfect mixing within each zone, which can lead to significant discrepancies compared to CFD predictions, especially under complex airflow configurations. To address this limitation, this study proposes a correction model that modifies the nodal scalar mass balance using a correction factor derived from CFD results. These factors are designed to recover CFD-based spatial average concentrations at steady state while preserving scalar mass conservation through consistency with steady state CFD outlet scalar mass fluxes. To limit the computational cost, an adjoint scalar transport approach is used, enabling the computation of correction factors for all possible emission positions from a number of CFD simulations only equal to twice the number of outlets, for a given geometry and airflow configuration. The method is evaluated on a multizone residential case under isothermal conditions. The results show that the proposed approach significantly improves the prediction of mean concentrations compared to the classical nodal approach, while maintaining a much lower computational cost than forward CFD simulations. Residual discrepancies are mainly associated with transient behaviour, due to the simplified dynamics of the nodal formulation. These results highlight the potential of the method

for improving scalar concentration predictions in practical isothermal applications, while also emphasizing that the correction factors remain dependent on the airflow configuration.

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Shen, Z., Qaum, M. S. U. I., Shrestha, S. S., Patil, S. M., Taran, M., Schmidt, M.*, et al.*

AI-assisted transient infrared imaging for shape-aware detection and quantification of building envelope air leakage.

Building and Environment, Vol. **307**, (2027)

Air leakage through building envelope increases energy demand, reduces occupant comfort, and creates moisture-related durability risks, yet accurately detecting leakage locations and quantifying airflow rates remain challenging with conventional diagnostic methods. This study develops and validates an AI-assisted transient infrared imaging (TIRI) framework for rapid, non-intrusive building envelope air leakage detection and airflow rate quantification. Laboratory experiments were conducted on gypsum board and brick cladding wall-panel specimens under controlled leakage openings, temperature differences, and pressure differences. The dataset includes 254 TIRI videos and 1820 leakage samples, covering pressure differences of 0.5–16.0 Pa, temperature differences of 4–14 °C, and airflow rates of 0.05–29.68 L/min. The framework integrates transient thermal evidence detection, Segment Anything Model (SAM)-based leakage segmentation, oriented bounding box standardization, and hybrid CNN–LSTM/MLP regression. SAM-derived masks are used to generate standardized 32 × 32 thermal video tensors and geometric descriptors for airflow prediction. The model achieved R^2 values of 0.96 and 0.85 for gypsum board and brick cladding specimens, respectively, indicating reliable performance across different envelope materials and leakage configurations. These results demonstrate that the AI-assisted TIRI framework can localize leakage regions and estimate airflow rates from transient infrared videos, which provides an automation-ready approach for quantitative envelope air leakage assessment.

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Porcu, A.

Analisi termoenergetica e confronto impiantistico per la riqualificazione di una palazzina uffici= Thermal-Energy Analysis and HVAC System Comparison for the Renovation of an Office Building.

Politecnico di Torino. Thèse 2026

La presente tesi analizza la riqualificazione termoenergetica e impiantistica della palazzina uffici MAIP, situata a Settimo Torinese, con l'obiettivo di valutare le prestazioni dell'edificio e confrontare diverse soluzioni HVAC applicabili al caso studio. Il lavoro nasce all'interno di un contesto progettuale reale, nel quale l'intervento riguarda sia l'involucro edilizio sia il sistema di climatizzazione, con particolare attenzione al rispetto del quadro normativo vigente e all'evoluzione dei Requisiti Minimi per gli edifici sottoposti a riqualificazione energetica. Dopo una prima analisi normativa, la tesi descrive il caso studio, la classificazione dell'intervento e le principali caratteristiche dell'edificio, distinguendo le zone climatizzate, i locali non climatizzati e gli ambienti serviti da ventilazione meccanica.
L'involucro viene analizzato attraverso le stratigrafie delle strutture opache, le prestazioni delle superfici vetrate e gli interventi previsti su copertura e facciata.

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Zheng, Y.

Análisis de técnicas de ensemble aplicadas a modelos de predicción de CO2 en espacios interiores.

Indoor air quality (IAQ) directly impacts human health and performance. In this context, carbon dioxide (CO2) concentration stands out not only as a critical toxicity indicator but also as an effective indirect proxy for human occupancy. Despite this, ventilation is traditionally managed reactively. This Bachelor's Thesis proposes transforming these systems into proactive solutions through forecasting models. The main

objective is to evaluate the performance of individual Machine Learning and Deep Learning algorithms against complex Ensemble Learning architectures to anticipate future CO2 levels. Using real time series captured by IoT sensors in offices and educational centers, prediction horizons ranging from 30 minutes to 4 hours are analyzed. The comparison evaluates accuracy (MAPE, RMSE, MAE) alongside computational cost. The results identify which configurations offer the best methodological balance to optimize environmental and spatial management in smart buildings.

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Laghezza, A., Yu, Y., Settimo, G., Capolongo, S., Gola, M.

Approccio data-driven alla valutazione dell'indoor air quality negli ambienti lavorativi: integrazione di sensori low-cost e percezione del comfort.

59° Congresso Nazionale della Società Italiana di Igiene. 21-24/10/2026. Genova

È risaputo che i sensori di Indoor Air Quality (IAQ), anche quelli considerati "low-cost", hanno un ruolo strategico nella promozione della salute; infatti, attraverso diverse modalità comunicano all'utente eventuali concentrazioni di inquinanti negli ambienti indoor (su rilevamento diretto o su base algoritmica). Nell'ambito della sanità pubblica ci si pone il seguente quesito: sono veramente efficaci tali rilevatori e possono influire sul miglioramento degli stili di vita? Proprio per questo motivo il lavoro di ricerca si è basato su una metodologia di analisi quali-quantitative dell'IAQ negli ambienti di lavoro. In particolare, il valore aggiunto della ricerca consiste nell'applicazione di un questionario qualitativo sul benessere degli utenti i cui esiti sono stati rapportati con analisi quantitative dei sensori low-cost di IAQ, spazi dipartimentali universitari ove è stato attivato un Living Lab.

Il est bien connu que les capteurs de qualité de l'air intérieur (QAI), même ceux considérés comme « à bas coût », jouent un rôle stratégique dans la promotion de la santé ; en effet, ils signalent à l'utilisateur, de différentes manières, d'éventuelles concentrations de polluants dans les environnements intérieurs (par détection directe ou sur la base d'algorithmes). Dans le domaine de la santé publique, la question suivante se pose : ces capteurs sont-ils réellement efficaces et peuvent-ils contribuer à l'amélioration des modes de vie ? C'est précisément pour cette raison que ce travail de recherche s'est appuyé sur une méthodologie d'analyse quali-quantitative de la QAI dans les lieux de travail. Plus précisément, la valeur ajoutée de cette recherche réside dans l'application d'un questionnaire qualitatif sur le bien-être des utilisateurs, dont les résultats ont été mis en relation avec des analyses quantitatives issues de capteurs de QAI à faible coût, dans des locaux universitaires où un « Living Lab » a été mis en place.

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Lee, S.-Y., Lee, J.-H., Yang, J.-Y., Kim, J.-W., Kim, J.-H., Yoo, W.-T.*, et al.*

Characterizing TVOC Increases and Terpene-Derived BVOC Contributions in Wood-Finished Public Facilities.

In: Atmosphere. 2026. pp. 887.

Total volatile organic compounds (TVOCs) are widely used to assess indoor air quality (IAQ). However, because TVOCs combine diverse compounds into a single metric, they cannot distinguish individual emission sources or chemical characteristics. Indoor environments with natural materials such as wood may emit biogenic volatile organic compounds (BVOCs), elevating TVOC concentrations and limiting the interpretation of indoor air quality. This study evaluated TVOC concentrations and chemical composition before and after installing wooden interiors in 36 public facilities in South Korea, including daycare centers, nursing homes, and welfare facilities. Domestic wood species, including Chamaecyparis obtusa, Larix kaempferi, and Cryptomeria japonica, cover approximately 49% of the interior surfaces. Major regulated VOCs, including benzene and toluene, did not increase significantly after installing wooden interior materials. Mean TVOC concentrations increased from 244.2 ± 139 to 640.1 ± 542.3 μg/m3, accompanied by significant increases in several terpene-related BVOCs, including α-pinene, myrcene, and cymene, as well as an increase in the absolute concentration of unidentified VOCs. Elevated TVOC concentrations in wood-based indoor environments may reflect compositional changes rather than poorer indoor air quality.

Therefore, TVOC concentrations should be interpreted alongside compound-specific analyses rather than relying solely on a single TVOC indicator.

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Caldas, G. K. C., Nunes, V. P. H., De Vasconcelos, A. F. F., Nunes, P. M.

Desenvolvimento de um analisador de compostos orgânicos voláteis com arduíno e sensor mq-138: uma proposta de baixo custo para aulas de análise instrumental em química.

Revista DCS, Vol. **23** n°(99), (2026), 1–33 p.

Os solventes presentes em tintas e vernizes, ao evaporarem, liberam Compostos Orgânicos Voláteis (COV) — poluentes atmosféricos que comprometem a qualidade do ar interno e expõem trabalhadores e usuários a riscos à saúde. No Brasil, inexiste norma regulamentadora específica para COV nesses produtos, e os métodos analíticos convencionais, como a cromatografia gasosa, demandam infraestrutura cara e pessoal especializado, limitando seu uso no ensino e no monitoramento rotineiro. Diante desse cenário, este trabalho apresenta o desenvolvimento de um analisador de baixo custo para quantificação de COV totais (COVT) em tintas e vernizes, utilizando uma placa Arduino Uno®, um sensor de condutividade térmica MQ-138 e um LED RGB, com custo total aproximado de R$ 350,00. O protótipo foi testado em três amostras de vernizes e quatro de tintas de diferentes marcas e composições, nos volumes de 3, 6 e 9 mL, com leituras realizadas por 30 minutos para cada volume, e os dados foram tratados pelo método de Correlação Linear de Pearson. A tinta à base de óleo (T3) apresentou a maior concentração de COV (522,33 ppm), enquanto as tintas aquosas (T1 e T2) exibiram os menores teores, em consonância com a literatura. O sistema demonstrou excelente estabilidade, reprodutibilidade (desvios-padrão < 7,5 ppm) e forte correlação linear (r ≥ 0,991) entre volume e concentração, validando sua confiabilidade analítica. Além de seu potencial para monitoramento ambiental e ocupacional, o protótipo destaca-se como ferramenta didática de alto valor pedagógico, permitindo que estudantes vivenciem princípios de instrumentação, aquisição de dados, sensores químicos e quimiometria em disciplinas de Análise Instrumental, bem como projetos interdisciplinares envolvendo Internet das Coisas (IoT) e cultura maker.

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Estriadi, A., Juju, J.

Design and Development of an IoT-Based Indoor Air Quality Monitoring and Control System Using the Tsukamoto Fuzzy Algorithm on a Dual-Core ESP32 Architecture.

Protek: Jurnal Ilmiah Teknik Elektro, Vol. **13** n°(3), (2026), 197–205 p.

Indoor air quality (IAQ) is a critical environmental health factor responsible for millions of cases of respiratory diseases each year. This study presents the design of an Internet of Things (IoT)-based indoor air circulation control system that integrates a BME680 sensor, an ESP32 microcontroller, and the Firebase Realtime Database platform with the Tsukamoto fuzzy logic algorithm as a control mechanism. This research implements a dual-core architecture on the ESP32, separating IoT communication tasks from sensor computation. This approach enables the BSEC algorithm to run consistently without interruption. The system uses two input variables (IAQ values and room temperature) as well as two actuators—a fan and a 12V DC blower—controlled via Pulse Width Modulation (PWM) signals based on 12 fuzzy rules. Testing was conducted in a miniature test chamber measuring 23.5 × 16 × 18 cm with controlled pollutant introduction. The research results show that the BME680 sensor has an average accuracy of 99.3% for temperature and 98.0% for humidity. All 12 fuzzy testing scenarios met the rule base criteria. The system was able to reduce the IAQ value from a very dirty condition (IAQ = 500) to a clean condition (IAQ ≤ 80) in an average time of 281 seconds. Data synchronization between the local LCD display and the Firebase-based mobile application achieved 100% accuracy. These results demonstrate that the Tsukamoto fuzzy method is effective in producing rule-based, stable, and proportional control for indoor air circulation systems.

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Agathokleous, S., Kedwell-Simmering, K., Casado, C., Asbach, C., Fonseca, A. S., Jensen, K. A.*, et al.*

Differences between PM2.5 chemical sources at semi-closed transport environments: comparing bus depots and metro platforms.

Environmental Research, Vol. **309**, (2026)

Chemical composition and source contributions of PM2.5 were investigated at a public-restricted bus depot in Valladolid (Spain) and two metro stations (Alto dos Moinhos and Quinta das Conchas) in Lisbon (Portugal) using positive matrix factorization (PMF). Locally derived sources dominated PM2.5 in both environments, with OC-rich combustion emissions prevailing at the bus depot and Fe-rich wear processes at the metro stations as major components. Trace element signatures (ng m−3) differed accordingly, with Zn dominating at the bus depot, reflecting tire wear and maintenance, and Mn prevailing at the metro stations, indicative of metro wear (e.g. rail–wheel–brake wear). Seven sources were resolved at the bus depot, led by mineral/construction (27.6%), followed by secondary sulfate (15.8%), tire wear (14.8%), exhaust (11.5%), washing/resuspension (11.4%), maintenance (9.9%), and brake wear (8.9%). However, both metro stations were dominated by metro wear emissions (~45–46%), with additional contributions from sea spray (~16–17.5%), secondary sulfate (8.4–16.5%), and mineral/construction (11.5–20.6%). Traffic-related infiltration was identified only at Alto dos Moinhos (8.1%), whereas biomass burning was resolved at Quinta das Conchas (9.7%). The different source profiles indicate the need for specific exposure-control strategies targeting indoor emissions, particularly combustion- and activity-related sources at the bus depot and mechanically generated metal-rich wear particles at the metro stations. Source-specific responses to air purifier operation suggest that filtration can complement source-control measures, although its effectiveness may depend on particle characteristics, spatiotemporal distribution, and continuous source generation. These findings support targeted air quality management in semi-closed transport environments.

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Lin, Y., Liu, S., Mao, T., Jia, W., Xia, H., Sun, P.*, et al.*

A dual-polarization cavity ring-down sensor enabling high sensitivity and wide dynamic range CO_2 monitoring.

Sensors and Actuators B: Chemical, Vol. **472**, (2027)

Monitoring CO_2 across urban atmospheric and elevated indoor levels requires both high sensitivity and tolerance to strong absorption, which are difficult to achieve simultaneously using a single cavity-loss condition in conventional cavity ring-down spectroscopy (CRDS). Here, we develop a dual-polarization single-cavity CRDS (DPS-CRDS) sensor that exploits polarization-dependent mirror reflectivity at oblique incidence to establish two complementary loss regimes within one triangular cavity. The low-loss S-polarization channel provides a longer ring-down time for sensitive urban atmospheric measurements, whereas the higher-loss P-polarization channel maintains measurable signals at elevated CO_2 concentrations. Allan deviation analysis yields minimum detectable absorption coefficients of 5.57×10^{-12} and 5.21×10^{-11} cm^{-1} for the S and P-polarization channels, respectively. Together, the channels enable quantitative CO_2 measurements from 50 to 10,000 ppm. Continuous measurements tracked occupancy and ventilation driven indoor CO_2 variations and resolved an urban atmospheric diurnal cycle that corresponded with changes in boundary layer height, wind speed, and solar irradiance. The proposed strategy therefore mitigates the sensitivity–dynamic range trade-off of conventional CRDS and enables wide range CO_2 monitoring within a single cavity.'

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Li, F., Wang, L., Nazar, S., Liang, H., Fang, S.

Dynamic gaseous pollutant source term estimation indoors with experiment-based impulse response and non-smooth competing priors.

Building and Environment, Vol. **307**, (2027)

Indoor gaseous pollutants receive increasing attention because of their hazardous health effects and long exposure times in buildings. Accurately estimating gaseous pollutant source terms indoors is critical for ensuring health, safety, and operational reliability. However, this is difficult because of complex thermal-flow boundaries in real buildings and non-smooth source releases. This study investigated the engineering feasibility and limitations of an experiment-based dynamic gaseous pollutant source term estimation (STE) framework. The proposed method utilized impulse responses derived from a full-scale experiment to model pollutant transport in a real-world test chamber, addressing inherent uncertainties through Monte Carlo simulations and filtering techniques. To solve the ill-posed inverse problem, non-smooth competing constraints (L1 and TV regularization) were incorporated to reconstruct dynamic source profiles. Unlike traditional manual trial-and-error approaches, an automated parameter selection strategy was established for the regularization parameter and L1-norm weighting. The results show that the algorithm incorporating L1 and TV regularization demonstrated superior performance in estimating dynamic source release rates compared with traditional Tikhonov and LSQR algorithms, reducing the average relative error by approximately 12% and 22%. When combined with the minimum residual method, exact-node spatial localization remained limited by the sparse downstream sensor layout in the confined indoor space. The true source location was identified in five of nine cases, while three cases resulted in adjacent-node misclassification and one case was not localized within the adjacent zone. This study improves the engineering practicality of the STE framework for safeguarding human health and safety in built environments.

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Olya, S. G. M., Miraboutalebi, S. M., Alinaghipour, B., Nguyen, T. V., Rainey, T.

Effects of additive integration on pore morphology and airflow resistance in cellulose nanofibril air filters.

International Journal of Biological Macromolecules, Vol. **384**, (2026)

Cellulose nanofibril (CNF, derived from renewable plant cell walls,) films fabricated via doctor blade-freeze-drying offer a potential sustainable platform for air filtration. However, how functional additive integration pathways alter pore morphology and airflow behaviour remains insufficiently understood. This study investigated how structural variation and two additive integration pathways influenced pore morphology, permeability, and filtration performance in doctor blade-freeze-dried CNF filters. Graphene oxide (GO) and green-synthesised ZIF-L (LE-ZIF-L) were selected as representative 2D sheet and microcrystalline additives. First, film thickness and CNF concentration were varied to establish baseline morphology-airflow and filtration relationships. Then, bulk incorporation and surface-localised deposition of selected additives were examined. Increasing film thickness and CNF concentration improved filtration efficiency by up to 9-fold but reduced permeability from (3.8 ± 0.4) × 10–11 to (8.1 ± 2.5) × 10–13 m2 while increasing normalised pressure drop. Bulk additive incorporation increased network densification and structural heterogeneity, yielding high normalised pressure drops for GO (24.9 ± 2.5 Pa.m2.g-1) and LE-ZIF-L (10.4 ± 2.1 Pa.m2.g-1), accompanied by reduced permeability. Surface-localised deposition of additives resulted in lower pressure drops than their bulk incorporation at the investigated loadings, but still increased airflow resistance relative to baseline CNF films, even at low mass loadings, likely due to restriction of surface pore entrances. Although 25-pass LE-ZIF-L deposition achieved the highest PM2.5 filtration efficiency (43.3%), the accompanying pressure loss prevented a substantial improvement in the filtration quality factor. Overall, the results demonstrated that structural modification and additive distribution altered pore morphology and airflow resistance, highlighting their importance in the design of doctor blade-freeze-dried CNF filters.

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Kashkouli, P. I., Brechtl, J., Kidder, M. K., Tsouris, C., Janke, C., Yang, C.-M.*, et al.*

Enhancing indoor air quality through amine functionalized polyacrylonitrile filters.

Environmental Science: Advances, (2026)

Indoor air purification systems with sorbent materials that capture pollutants can boost air recirculation, lower dependence on outdoor ventilation, and reduce peak loads. In this study, amine-functionalized polyacrylonitrile (PAN) fibers were developed and evaluated as candidate filter media for carbon dioxide (CO2) capture from indoor air. The performance of the modified fibers was investigated using wind-tunnel experiments under controlled environmental conditions. Under dynamic airflow, the sorbent exhibited measurable CO2 uptake while maintaining a low pressure drop across the filter module. A 72 hour continuous-operation test demonstrated CO2 removal and moisture interaction throughout the testing period. A steady-state indoor air mass balance further showed that incorporating a CO2-selective filter could reduce outdoor air ventilation requirements by up to 40% under ideal conditions. Finally, a system-level scaling analysis estimated a sorbent requirement of approximately 2.7 kg per occupant to offset 30% of daily CO2 generation. Overall, the results indicate that amine-functionalized PAN fibers, as regenerable and scalable sorbents, show potential for integration into building systems for indoor air quality improvement and air treatment applications.

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Jasmine, L. S., Bakar, M. E. B. A.

Experimental Evaluation of Open Terrarium Systems as Passive Biofiltration Modules for Smart and Sustainable Office Buildings.

2026 13th International Conference on ICT for Smart Society (ICISS)

Indoor Air Quality (IAQ) has become one of the primary concerns in modern office buildings, since it affects the health, productivity, and energy consumption of the occupants, especially in tropical countries where mechanical ventilation systems run continuously. Although nature-based solutions are being identified as sustainable measures to improve indoor environmental quality, the application of open terrarium systems as localized, passive biofiltration units has not been well understood. In this study, the performance of open terrarium systems to enhance indoor air quality in a tropical cubicle office building was evaluated by performing two phases of experimental investigation at the Administration Office of Perpustakaan Sultanah Zanariah, Universiti Teknologi Malaysia Kuala Lumpur. The final results of Phase One determined the best mix of interior plant species to lower the levels of Total Volatile Organic Compounds (TVOCs), carbon dioxide (CO2), and control relative humidity (RH). Phase Two evaluated four different terrarium configurations in a cubicle scenario (0%, 2%, 4%, and 6%) and compared their performance against the recommendations of MS 1525, Green Building Index (GBI), and GreenRE. The results showed that all the sets of terrariums enhanced indoor environmental quality with humidity levels within the suggested comfort zone. The 6% configuration achieved the most overall pollutant reduction, while the 4% configuration delivered the most balanced solution, incorporating environmental benefits and workspace usability. The results show that open terrarium systems can serve as complementary passive biofiltration systems for sustainable indoor environmental management and could be integrated with future smart building monitoring systems to create a healthier and more resilient building atmosphere.

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Rk Jois, A Redlein, Morillo-Napetschnig, E.

Exploring the Impact of Workplace Experience (WX) as a Strategic Attractor supporting RTO and Presence Strategies – A Literature Review enlarged with Expert Interviews.

Transdisciplinary Workplace Research (TWR) Conference, 2026

“Return-to-Office”(RTO) is currently one of the major topics in Workplace Management many companies are making efforts to bring their employees back to the office. Some are trying to achieve this through a code of conduct and RTO Mandates. Others focus on employees’ needs and optimising the work environment through improved Workplace Experiences (WX) enhanced by Employee Experiences (EX).

In this context, this paper examines: How Workplace Experience (WX) supports RTO and Presence Strategies (PS) through voluntary attendance as an Attractor in hybrid work environments? Which goals, components, and metrics of WX shape policies? First, a literature review was conducted. The acquired

results were, in a second step, verified and expanded through qualitative expert interviews with ten C-level and executive leaders to enhance reliability and scope. The interview data were analyzed thematically. This study bridges theoretical WX frameworks with practitioners' knowledge and input on factors, revealing the state-of-the-art in work management trends. The findings of this paper support the complex design process of creating a successful WX. A systematic understanding of the dimensions and facets, the strategic goals and metrics of this heterogeneous, multi-structured "conglomerate" is a prerequisite for unique solutions tailored to the specific use case. This paper offers a comprehensive list of factors and dimensions of WX components that practitioners can use to create and measure an effective office PS operationalized by WX. The findings help practitioners learn to prioritize investments and identify practical steps to support RTO-encouragements and PS in hybrid environments with voluntary attendance.

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Wang, Z., Lausch, K. H., Lichtner, E., Ramasetti, E. K., Kriegel, M.

A Fourier neural operator framework for indoor contaminant transport prediction, source localization, and release strength estimation.

Building and Environment, Vol. **307**, (2027)

Indoor air quality is a key concern in building design, as occupant exposure is strongly governed by pollutant transport and removal through ventilation flows. Computational fluid dynamics (CFD) provides detailed indoor contaminant concentration fields, but its computational cost limits repeated evaluations over many pollutant source locations. In this work, we develop a Fourier neural operator (FNO) framework for rapid prediction and inverse localization of indoor contaminant transport, in which a soft rectangular source mask provides geometric fidelity and differentiability. It is evaluated in the two-dimensional IEA Annex 20 room with fixed geometry and prescribed ventilation. The FNO achieves a mean relative L2 error of 0.0326±0.0022 over three training seeds, predicts a full field in approximately 0.64 ms, about 1.3×105 times faster than the CFD workflow, and yields lower errors than a fully convolutional network (FCN), U-Net, DeepONet, and inverse-distance weighting (IDW), with accuracy comparable to the geometry-informed neural operator (GINO). A model trained at 192×64 transfers directly to the 384×128 grid with an error of 0.0360±0.0021. For inverse localization, the surrogate is combined with coarse global screening and gradient-based refinement, achieving mean localization errors of 0.103, 0.165, and 0.372 m with eight sensors at relative noise levels of 0, 0.02, and 0.05. For 15 off-grid sources with unknown release strengths, locations and strength are estimated jointly with noise-free mean errors of 0.126±0.007 m and 0.106±0.009. These results demonstrate that neural-operator surrogates can support field prediction and inverse source localization within the evaluated setting.

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Mandhyan, M.

Fundamentals of Indoor Air Pollution: Sources, Composition, Dynamics, and Health Implications.

In: Integrating Nanotechnology and AI to Address Air and Noise Pollution. Springer Nature Switzerland; 2027. 129–141 p.

The problem of indoor air pollution is a serious and under-acknowledged public health problem that has a great impact on human well-being, especially in the developing world where individuals spend a significant amount of their time indoors. In contrast to the outdoor pollution, indoor air pollutants are caused by the daily activities of cooking, cleaning, heating, as well as using the synthetic materials and consumer products. These sources release a compound of multiple pollutants, such as particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO2), and biological pollutants like molds and allergens. Poor ventilation systems found in most homes and workplaces contribute to the increase in the number of pollutants, which results in the onset of respiratory complications, heart-related complications, and other health-related effects in the long term. In this chapter, the categorization of the most common indoor air pollutants, their origins, health impacts, the existing monitoring tools, and the best mitigation measures is examined. It highlights the importance of evidence-

based strategies and interdisciplinary frameworks of managing healthier indoors environments, policy interventions, and the necessity of regarding indoor air quality management on a global scale.

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Zhao, T., Xu, Z., Yang, Y., Wang, Z.

Gradient mixed-amine architecture on N/P/O co-doped porous carbon for efficient and stable CO2 capture from indoor air.

Separation and Purification Technology, Vol. **423**, (2027)

Solid amine adsorbents are promising materials for CO2 capture from indoor air, but their practical application is often limited by the trade-offs among high adsorption capacity, amine retention, diffusion accessibility, and stability under humid cyclic operation. Herein, we report a gradient mixed-amine solid adsorbent constructed on N/P/O co-doped porous carbon through KHCO3-regulated pore engineering and the sequential loading of TEPA and PEI. The optimized 1 K carbon support provides a well-balanced pore structure that enables efficient amine confinement while maintaining accessible pathways for CO2 transport. Spectroscopic analyses and density functional theory calculations show that pyridinic N and oxygen-containing phosphorus species on the carbon surface strengthen amine immobilization through cooperative noncovalent interactions while preserving reactive amine sites. The sequential loading of tetraethylenepentamine (TEPA) followed by polyethyleneimine (PEI) constructs a spatially differentiated amine architecture, in which the TEPA-rich inner region provides high CO2 reactivity, while the PEI-containing outer region improves amine retention and cycling stability. The optimized 1 K-T4P1 adsorbent exhibits a CO2 uptake of 2.21 mmol g−1 at 55 °C under dry 3000 ppm CO2/N2 and a markedly enhanced capacity of 3.80 mmol g−1 at 25 °C and 50% RH. Moreover, 1 K-T4P1 retains approximately 86% of its initial capacity after ten dry adsorption–desorption cycles and approximately 85% after ten humid cycles. These results demonstrate that integrating pore-structure regulation, heteroatom-assisted interfacial anchoring, and gradient mixed-amine engineering is an effective strategy for developing efficient and stable solid amine adsorbents for indoor CO2 capture.

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Swathi, M., Nagaraju, P., Sarika Yadav, S., Begum, S.

Hierarchical NiO-CdO heterostructured thin films with enhanced acetone sensing performance at room temperature.

Next Materials, Vol. **13**, (2026)

Nickel oxide (NiO) and NiO-CdO composite thin films with different CdO contents (20, 40, and 60 wt%) were successfully deposited on glass substrates by a simple and cost-effective chemical spray pyrolysis technique and investigated for room-temperature acetone sensing applications. The structural, morphological, and surface chemical properties of the deposited films were systematically characterized using X-ray diffraction (XRD), Raman spectroscopy, field-emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), selected-area electron diffraction (SAED), and X-ray photoelectron spectroscopy (XPS). XRD analysis confirmed the coexistence of crystalline cubic NiO and CdO phases without secondary impurities, indicating successful heterostructure formation. Raman and XPS analyses further verified the incorporation of CdO and the presence of defect-rich NiO-CdO interfaces. FESEM and TEM investigations revealed that CdO incorporation transformed the compact granular morphology of pure NiO into an interconnected porous network with abundant heterojunction interfaces, providing enhanced surface area and efficient gas diffusion pathways. Gas-sensing studies performed under ambient conditions demonstrated a significant improvement in acetone sensing after CdO incorporation. The 60 wt% NiO-40 wt% CdO composites exhibited the best sensing performance, showing a maximum response of 25.2 toward 10 ppm acetone at room temperature, approximately three times higher than that of pure NiO. The composite sensor also exhibited excellent selectivity toward acetone over benzene, formaldehyde, ethanol, and methanol, together with rapid response and recovery times of 30 s and 37 s, respectively. The enhanced sensing characteristics are attributed to the synergistic effects of the

NiO-CdO p-n heterojunction, increased oxygen adsorption, improved charge transfer, and the highly porous hierarchical morphology. These results demonstrate that NiO-CdO composite thin films synthesized by spray pyrolysis are promising candidates for low-cost, room-temperature acetone sensing in environmental monitoring.

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Tavakkalovich, I. D.

Hygienic assessment of indoor air ventilation and ventilation systems.

BG pulse journal, Vol. **2** n°(10), (2026), 1174–1176 p.

Indoor air quality is a major determinant of human health because modern populations spend most of their daily lives in enclosed spaces. Ventilation systems play an essential role in maintaining acceptable microclimatic conditions by regulating temperature, humidity, air velocity, and contaminant concentrations. This article evaluates the hygienic significance of ventilation systems and analyzes criteria used to assess their effectiveness. A narrative review and hygienic analysis were conducted using public health principles and environmental hygiene standards. The results indicate that adequate air exchange significantly reduces carbon dioxide accumulation, excessive humidity, dust, microorganisms, and unpleasant odors. Effective ventilation improves comfort, cognitive performance, occupational productivity, and disease prevention. The study highlights the importance of monitoring air exchange rates, carbon dioxide concentrations, thermal conditions, and ventilation-system performance as core indicators of hygienic safety.

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Rama Prasatya, I.

Implementation of mqtt broker and gemini api in an internet of things based indoor air pollution monitoring system.

Universitas Pendidikan Ganesha

Cette étude a pour objectif de concevoir, de mettre en œuvre et d'évaluer la facilité d'utilisation d'un système de surveillance de la pollution de l'air intérieur basé sur l'Internet des objets (IoT) et intégré à un broker MQTT et à l'API Gemini. Ce système repose sur une architecture à trois niveaux comprenant du matériel IoT, un serveur backend basé sur Laravel et une application mobile basée sur Flutter. Le matériel utilise un Arduino Nano pour la lecture des données provenant des capteurs MQ-7 (CO) et Sharp GP2Y1010AU0F (PM 2,5), ainsi qu'un Arduino Nano et un ESP32 comme passerelles de communication sans fil. La transmission des données des appareils IoT vers le serveur est gérée à l'aide du protocole de communication MQTT, puis celles-ci sont stockées dans la base de données de séries chronologiques InfluxDB. L'API Gemini est intégrée en tant que moteur analytique intelligent qui traite les statistiques issues des données historiques des capteurs afin de générer automatiquement une classification de la qualité de l'air, un résumé des conditions et des recommandations sanitaires, conformément aux directives de l'Indice de qualité de l'air intérieur (IAQI). Les résultats des tests de fonctionnalité réalisés selon la méthode « boîte noire » montrent que les 13 scénarios du système fonctionnent correctement, et que les recommandations générées par le modèle d'intelligence artificielle ont été validées avec précision par des experts en génie environnemental. Les tests d'ergonomie, évalués à l'aide de l'échelle d'ergonomie des systèmes (SUS) auprès de 30 participants, ont donné un score moyen de 70,583, ce qui correspond à la catégorie « Bon ». Cela montre que l'ensemble du système de surveillance développé fonctionne de manière réactive en temps réel, qu'il est facile à utiliser et qu'il fournit efficacement aux utilisateurs des informations analytiques sur la pollution atmosphérique.

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Anttila, E., Vornanen-Winqvist, C., Clinchard, S., Korja, N., Mikkola, R., Alapieti, T.*, et al.*

Indoor air quality aboard cruise ships: Utilizing survey and monitoring approaches.

Environmental Advances, Vol. **26**, (2026)

Indoor environment quality (IEQ) aboard cruise ships is a critical factor affecting the health, comfort, and productivity of crew and passengers, but remains understudied compared to schools, offices, and hospitals. To bridge this gap, the present study employs, separately, both occupant surveys and continuous indoor air quality (IAQ) monitoring aboard a cruise ship. This dual approach, not previously undertaken on cruise ships, aims to provide comprehensive insights into the measured and perceived environmental conditions on board. The study was conducted on a cruise ship on the Baltic Sea and involved surveying 391 crew members in October 2023 to assess their dissatisfaction with the indoor environment across various workstations. Additionally, real-time sensors measured essential IAQ parameters (temperature, relative humidity (RH), particulate matter, carbon dioxide, and total volatile organic compounds) from October to December 2024. Conditions on board the ship were largely acceptable. Survey results indicate considerable variation in dissatisfaction levels, with noise emerging as a significant source of dissatisfaction, particularly in drinking establishments. Sensor monitoring recorded low RH levels in multiple measurement locations, especially at the command bridge, alongside with high temperatures in nightclub areas. Otherwise, pollutant levels generally aligned with expected standards, except for isolated spikes. Based on the study findings, a few targeted improvement suggestions could be made to enhance the indoor comfort and air quality, such as installing air humidifiers. Further research should expand to monitor noise levels, include passengers and other cruise operators in surveys, address seasonal variations, and explore additional environmental factors.

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Nyembwe, J.-P. K., Ogundiran, J. O., Simões, N. A., Silva, M. G.

Indoor Climate Performance in Intensive Care Units: A Seasonal Field Study in the Democratic Republic of the Congo.

In: Hygiene. 2026. pp. 69.

Indoor environmental quality (IEQ) in naturally ventilated hospitals presents significant challenges in tropical regions, where seasonal climatic variability and limited environmental control may compromise indoor air quality (IAQ) and thermal comfort (TC). However, comparative field evidence from African healthcare facilities remains limited. This study investigated seasonal IEQ conditions in two naturally ventilated intensive care units (ICUs) in the Democratic Republic of the Congo (DRC). Environmental monitoring and questionnaire-based assessments were conducted during rainy and dry seasons at Jason Sendwe Hospital (JSH), Lubumbashi, and Hôpital du Cinquantenaire (HDC), Kinshasa. Measurements included operative temperature, relative humidity, CO2, PM2.5, PM10, and a VOC-based IAQ index. Subjective assessments from 348 healthcare workers examined perceived IAQ, thermal sensation, and self-reported symptoms. Exploratory PMV–PPD calculations complemented the thermal assessment. The CO2 concentrations ranged from 1977 to 2600 ppm at JSH and 1437–2733 ppm at HDC, with higher values during the dry season. Reported PM2.5 concentrations reached 228 and 237 µg/m3, respectively, indicating potentially substantial particulate pollution. VOC-based IAQ indices were higher during the rainy season. At JSH, 80% and 74% of respondents rated IAQ as poor or very poor during rainy and dry seasons, respectively. Both hospitals exhibited a pronounced seasonal reversal in thermal conditions, characterized by warm rainy-season conditions and predominantly cold dry-season thermal sensations. Exploratory PMV–PPD estimates indicated greater predicted warm discomfort at HDC. The findings identify a dual seasonal thermal challenge in naturally ventilated tropical ICUs, where warm-season and cool-season discomfort coexist with substantial IAQ concerns. By demonstrating this pattern across hospitals in contrasting climatic and urban environments, the study extends existing evidence beyond the predominant focus on overheating and highlights the need for integrated, seasonally adaptive ventilation and pollutant-control strategies in resource-constrained healthcare facilities.

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Evgeniya, A., Andrew, K.

Integrated approaches to improve indoor air quality monitoring and control systems performance.

Journal ID, Vol. **4825**, (2026)

Purpose – This paper examines integrated approaches for enhancing theperformance of indoor air quality (IAQ) monitoring and control systems. It aims tosynthesize sensing technologies, data analytics, and automated control strategies toimprove environmental health and energy efficiency.Design/methodology/approach – A multidisciplinary framework is adopted,combining sensor network design, Internet of Things (IoT) architectures, machinelearning–based prediction models, and adaptive HVAC control systems. Comparativeanalysis of existing systems and conceptual modeling are used to evaluate performanceimprovements.Findings – The study finds that integrated IAQ systems leveraging real-timesensing, predictive analytics, and automated actuation significantly improve pollutant detection accuracy, response time, and energy efficiency. Hybrid models outperformtraditional rule-based systems in dynamic indoor environments.Practical implications – The proposed approach supports building managers,engineers, and policymakers in deploying scalable IAQ solutions. It enables healthierindoor environments in residential, commercial, and institutional buildings whilereducing operational costs.Originality/value – This paper contributes a unified framework that integratessensing, analytics, and control, addressing fragmentation in existing IAQ solutions andproposing a systems-level optimization perspective.

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Sari, D. A., Sunardi, D., Wibowo, S. H., Wijaya, A.

Internet of Things (IoT)-Based Air Quality Monitoring Using An MQ-135 Sensor.

Jurnal Multidisiplin Dehasen (MUDE), Vol. **5** n°(4), (2026), 2235–2244 p.

This study aims to design and develop an air quality detection system using the MQ-135 sensor based on the Internet of Things (IoT), enabling air quality conditions to be monitored remotely through the internet. The research employed a quantitative method with an experimental approach, while the system was developed using the prototype method. The research stages included literature review, system design, hardware and software development, system testing, data collection, data analysis, and conclusion drawing. The developed system utilizes the MQ-135 sensor as a gas detector and the NodeMCU ESP8266 as the microcontroller, which is connected to the ThingSpeak platform to transmit, store, and display measurement data in real time. Testing was conducted in two indoor environments, namely a bedroom without air conditioning (AC) and a kitchen immediately after cooking activities. The test results showed that all system components functioned properly, the sensor was able to detect changes in air quality, and the measured data were successfully transmitted and visualized on the ThingSpeak platform via the internet. Based on the measurement results, the air quality in the kitchen after cooking showed higher sensor readings than that in the bedroom without air conditioning (AC), indicating poorer air quality. Therefore, the developed system is capable of monitoring indoor air quality in real time, providing information on air quality conditions, and serving as an Internet of Things (IoT)-based air quality monitoring system.

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Jayarajan, S., Andrew, A. M., Koilpillai, C. S. S., Tan, E. S. M. M.

Investigating the Correlation of Scorched Fire Materials to the Indoor Air Quality Using Deep Learning.

2026 2nd International Conference on Electrical, Robotics and Intelligent Systems (ELECRIS)

Fire-related indoor air pollution is an increasing concern due to the emission of hazardous pollutants during fire incidents. This study explores the relationship between scorched fire materials and indoor air quality (IAQ) using deep learning techniques. Ten materials were heated at controlled temperatures of 50◦C,75◦C, and 100°C, while real-time data including CO, CO2, VOCs, and PM10 were captured using IAQ sensors. After data normalization and clustering into IAQ categories, namely Good, Moderate, and Poor, four deep learning models comprising LSTM, Bi-LSTM, GRU, and Transformer were trained to classify air quality. Evaluation based on accuracy, precision, recall, and F1-score revealed that the Transformer model achieved the highest performance, with an accuracy of 99.6% and an F1-score of 99.3%. This research

demonstrates the potential of integrating AI-based IAQ classification into early fire detection and response systems.

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Mutaufiq, M., Sulistyo, H., Berman, E. T., Sumardi, K., Nuryadi, A. R.

Investigation and Adaptation of a Precision Air Conditioning System for Practical Laboratory Learning.

FLYWHEEL: Jurnal Teknik Mesin Untirta, Vol. **12** n°(2), (2026), 115–123 p.

Precision Air Conditioning (PAC) is a type of advanced cooling machine with features that enable the cooling process to be carried out more efficiently and effectively. This tool is very suitable for use as a learning tool for practical work. However, PAC cannot be directly adopted, but needs to be conditioned so that it can be used as a learning medium for practical work. This study aims to investigate and adapt the PAC cooling machine so that it can be optimized as a learning medium. The PAC investigation aims to determine the feasibility of the performance of a used PAC cooling machine for use as a practical tool. Then the PAC adaptation aims to add the necessary tools and materials so that the PAC is ready for use for practical activities The research uses the R&D (Research and Development) method to produce PAC demonstration tools with the stages of concept, design, collecting materials, assembly, and testing. The trial was conducted to determine the PAC performance parameters, including air temperature, Refrigeration Effect (RE), Compression Works (CW), and Coefficient of Performance (COP). According to the test results, that the PAC cooling machine can operate well after being adapted as a practical demonstration tool. The PAC cooling machine can produce supply air with a minimum temperature of 16.4 oC. Furthermore, the PAC performance calculation results show an RE value of 136.65 kJ/kg, a CW value of 36.26 kJ/kg, and a COP value of 3.84.

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Morantes, G., Babich, F., Lollini, R., Sherman, M., Molina, C., jones, B.

Monetary Costs of Office Air Contaminants.

IEQ 2025 Rising to New Challenges: Connecting IEQ to a Sustainable Future (Montreal, 24/09/2025–26/09/2025)

Offices expose adult populations to airborne contaminants for several hours each working day. To support practical cost–benefit thinking for indoor air quality (IAQ), we combine (i) office concentration evidence from global sampling studies, (ii) contaminant-specific harm expressed in Disability-Adjusted Life Years (DALYs), and (iii) published monetary values per averted DALY for very-high Human Development Index settings. The output is an annual monetary burden per person for priority contaminants. Results highlight particulate matter (PM) as the dominant cost driver, suggesting a clear focus for cost-effective IAQ interventions in offices.Building decisions often compare intervention costs (filtration, source control, ventilation strategies) against energy or maintenance budgets, while health impacts remain difficult to express on the same scale. DALYs provide a single harm metric that combines years of life lost and years lived with disability. By assigning a monetary value to an averted DALY, office contaminant exposure can be translated into an annual economic burden that is directly comparable with the cost of control strategies [1]. This does not replace compliance or comfort-based assessments; it provides an additional, health-centred lens for prioritising interventions.

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Tekler, Z. D., Roberts, B., Low, R., Cook, M.

Multi-horizon forecasting of thermal and ventilation risks in naturally ventilated hospitals using multi-output transformers.

46th AIVC Conference in Innovations in Smart Ventilation and IEQ for Resilient and Adaptive Buildings (AIVC 2026). Incheon, Republic of Korea.

Hospital wards in tropical regions face sustained challenges in maintaining acceptable thermal comfort and indoor air quality, particularly where mechanical cooling and ventilation are not available. This study presents a multihorizon forecasting framework for indoor environmental risks in naturally ventilated healthcare settings. The framework draws on more than two years of 15-minute interval sensor measurements collected from 14 wards across two regional hospitals in Tamale, Ghana, paired with weather data, to forecast indoor air temperature, relative humidity (RH), and carbon dioxide (CO2) concentration over a 24-hour horizon. We benchmark a Temporal Fusion Transformer (TFT) against a multi-output XGBoost baseline, while current environmental risk is summarised against international standards at ward-level. The risk summary indicates that overheating and elevated humidity are widespread across the monitored wards, whereas CO2 exceedance is concentrated in a smaller number of high-risk spaces, particularly neonatal and paediatric wards. Model results show that the TFT meaningfully outperforms XGBoost for temperature and RH forecasting, reducing error by approximately 32% and 35–42%, respectively, across MAE, RMSE, and MAPE, while CO2 forecasting remains more challenging and is better served by the XGBoost. The proposed framework provides a basis for targeted ventilation management and demonstrates the feasibility of low-cost, health-oriented indoor climate forecasting in low-resource tropical hospitals.

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Li, J., Fu, Y., Xiao, R., Wei, C., Zhang, L., Lv, Y.

Multi-wavelength cataluminescence fingerprint sensing of aldehydes and ketones on star-shaped zirconia.

Microchemical Journal, Vol. **231**, (2026)

Aldehydes and ketones (AKs) are volatile organic compounds (VOCs) of significant environmental and health concern, requiring rapid and reliable detection methods. In this study, we propose a multi-wavelength array cataluminescence (CTL) strategy employing morphology-controlled star-shaped zirconia (SZ) as the sole sensing element for efficient AKs identification. By integrating CTL intensity and response time across multiple wavelengths on a single star-shaped zirconia (SZ) sensing element, we established optical-kinetic fingerprint spectra that enable rapid discrimination of five common AKs (propionaldehyde, acetone, n-butyraldehyde, isobutyraldehyde, and butanone). Meanwhile, the system exhibited detection limits in the range of 0.16–2.08 ppm for the five AKs over 30 days, confirming its high sensitivity and good stability. This study proposes a new wavelength-modulated CTL fingerprint recognition strategy, providing an approach for rapid trace detection of volatile organic compounds. Different from our previous fingerprint strategies that relied on temperature or material arrays as discriminating dimensions, this work highlights morphology-controlled zirconia as the core enhancer of cataluminescence performance, and integrates multi-wavelength optical-kinetic fingerprints to achieve single-material identification of AKs.

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Korkmaz, H., Terecİ, A.

Ofis Binalarında İç Mekân Hava Kalitesinin Ölçümler ve Kullanıcı Algısı Üzerinden Değerlendirilmesi: Konya Selçuklu Belediyesi Hizmet Binası Örneği.(Évaluation de la qualité de l'air intérieur dans les immeubles de bureaux à partir de mesures et de la perception des utilisateurs : l'exemple du bâtiment administratif de la municipalité de Selçuklu à Konya).

TUDEJ Thinking Of Urban Decoding Journal, (2026)

Cet article a pour objectif d'évaluer les effets des systèmes de ventilation naturelle et mécanique sur la qualité de l'air intérieur dans les immeubles de bureaux, à partir de mesures expérimentales et de données relatives à la satisfaction des utilisateurs. L'étude a été menée dans le bâtiment administratif de la municipalité de Selçuklu à Konya, qui accueille un nombre important d'utilisateurs, et quatre bureaux présentant des caractéristiques d'utilisation différentes ont été sélectionnés comme échantillon. Dans le cadre de cette étude, les températures, l'humidité relative, les concentrations de dioxyde de carbone (CO_2) et de $PM_{2,5}$ ont été mesurées en été et en hiver, et les données relatives à l'environnement intérieur ont été

comparées à la qualité de l'air extérieur. De plus, la relation entre les conditions de l'environnement physique et la santé ainsi que le confort des utilisateurs a été examinée à l'aide d'une enquête de satisfaction menée auprès de 33 employés. [...] En conclusion, il est recommandé, pour améliorer la qualité de l'air intérieur dans les bâtiments publics, de favoriser la ventilation naturelle, de mettre en place des systèmes de ventilation à la demande équipés de capteurs de CO_2 et d'élaborer des stratégies d'exploitation axées sur les utilisateurs.

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Suyambazhahan, S., Swami Punniyakodi, B. M., Sathyanarayanan, S.

Performance enhancement and sustainability of desiccant air-conditioning systems using solar energy regeneration for industrial applications.

Journal of Thermal Analysis and Calorimetry, (2026)

Presently, air-conditioning systems pose a significant strain on the global electricity grid, accounting for >40% and 36% of peak electricity demand (about 3/4 of global energy consumption) in industrial buildings and the residential sector, respectively. The condensation cooling technique in conventional systems is responsible for high-energy consumption and costs. A desiccant cooling system is among the best options for addressing future energy demand. Both solid and liquid desiccant systems offer high performance, depending on the specific application and environmental conditions. The present study focused on a vapor compression-based solid desiccant air-conditioning system (hybrid) to meet global energy demand, cost, and indoor air quality. The hybrid system reduces operating costs and achieves a 17.3% energy savings, as well as provides long-term stable dehumidification and regeneration performance. The mean COP of desiccant cooling systems increases from 0.96 to 1.25, a 50% increase over that of the conventional vapor absorption system. The thermodynamic analysis showed that the proposed system attained a higher COP of 18.6% and 16.3% while using hot air and ambient air, respectively. The combined use of electrical and solar heating methods enhances and delivers the best performance, ranging from 13.94 to 33.04%, at a regeneration temperature of 60 °C and an air front velocity of 1.3 m s–1, and offers energy savings due to the utilization of the thermal recovery unit, reaching 28.7%, The proposed configuration has the potential to save the life cycle cost by a rate of up to 33%, reduces energy consumption by 20–50%, and increases cooling capacity by 3–4 times compared to the Reference Desiccant Cooling System with a payback period of around 6 years as well as the sustainability of air-conditioning technologies. Also, in the summer, winter, and rainy seasons, regeneration effectiveness increased with increasing inlet air temperature and decreased with increasing inlet air velocity because, as the air temperature increases, the density of air decreases, thus reducing the mass flow rate and increasing the dry-bulb temperature of the process outlet air.

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Ma, Y., Ye, W.

Physical object oriented modeling framework for computational fluid dynamics in room-scale airflow simulation.

Advanced Engineering Informatics, Vol. **77**, (2027)

Computational fluid dynamics (CFD) is essential for airflow simulations in the built environments, yet its adoption is hindered by expertise-intensive, manual setup processes rooted in a solver-centric framework. This study proposes the physical object oriented modeling (POOM) framework to automate and democratize CFD for room-scale airflow simulations. POOM represents building components (e.g., an air conditioner's air outlet, furniture) as reusable, self-contained objects through model encapsulation, integrates their properties via variable mapping, and translates engineering intent into solver inputs using coordination functions. We implement a POOM-based framework that automates the simulation pipeline from CAD drawings to OpenFOAM. Furthermore, based on POOM, we develop a large-language-model-driven simulation agent and a multi-platform, web-based interaction interface, demonstrating the framework's potential to democratize simulations. Quantified by a novel and conceptual simulation logic

complexity (SLC) metric, POOM significantly reduces setup complexity in an office airflow case for demonstration purposes, primarily through object reuse. This framework shifts CFD from a fragmented, tool-related activity to an object-centric, automated workflow, establishing a foundation for intelligent and collaborative simulation ecosystems.

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Kumar, R. R., Punetha, D.

Poly(vinylidene fluoride) for Gas/VOC Sensing: Fundamentals and Applications.

IEEE Sensors Reviews, Vol. **3**, (2026), 813–857 p.

This review provides a systematic and critical overview of PVDF-based sensing systems, encompassing material fundamentals, fabrication methodologies, and sensing mechanisms. Particular emphasis is placed on crystalline phase engineering, where the transformation from the nonpolar α-phase to the electroactive β-phase significantly enhances dipole alignment, polarization, and overall sensing performance. Key fabrication strategies, including solution casting, electrospinning, phase inversion, melt processing, and emerging additive manufacturing techniques, are examined with respect to their influence on morphology, porosity, and charge transport characteristics. The review further elucidates diverse sensing mechanisms, such as adsorption-induced charge modulation, chemiresistive, electrochemical, capacitive, and optical transduction, demonstrating the multifunctional sensing capability of PVDF.

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Wang, S., Guo, Z., Zhang, Y., Guan, H.

Prediction of formaldehyde emission from wood-based panel furniture in different indoor environments and human health risk assessment.

International Communications in Heat and Mass Transfer, Vol. **180**, (2026)

Wood-based panel furniture is the primary source of indoor formaldehyde emissions. However, limited studies have investigated its release characteristics under different geometries of furniture systems and associated human health risks. In this study, formaldehyde release behavior in four typical functional indoor settings was analyzed accounting for multisource and multidimensional furniture-driven processes, and human exposure as well as carcinogenic and non-carcinogenic risks were systematically evaluated. A cylindrical mass transfer model was developed, where key release parameters were determined from environmental chamber experiments. Numerical simulations of cylindrical and rectangular furniture geometries were performed to analyze formaldehyde concentration dynamics under periodic ventilation and the influence of geometry on emission behavior. It was found that the rectangular prism panel showed higher initial emission rates but faster later-stage concentration decay than cylindrical panel under strictly identical volume and height conditions. Additionally, the formaldehyde concentration with closed windows is approximately 21-fold higher compared with ventilated conditions at 600 h. The indoor steady-state formaldehyde concentration was determined using a multi-source coupled mass transfer model, which was further applied in the risk assessment, showing that inhalation exposure is approximately 216 times that of dermal exposure. Furthermore, the health risk assessment indicated that non-carcinogenic risks remained acceptable across all scenarios, while carcinogenic risks showed scenario-dependent variations due to differences in formaldehyde exposure conditions. These findings provide a scientific basis for the development of improved indoor air quality management strategies for formaldehyde mitigation.

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Garzia, F., Pozza, C., Audenaert, A., Verbeke, S.

Quantifying non-energy co-benefits of building automation upgrades in offices: a simulation-based IAQ assessment under parametric uncertainty.

Developments in the Built Environment, Vol. **28**, (2026)

Building Automation and Control Systems allow office technical systems to respond to changing indoor and outdoor conditions, improving indoor air quality and potentially affecting occupant health and performance. However, whether these co-benefits are large enough to inform investment decisions remains unclear. This study addresses this gap through a simulation-based framework that estimates their economic relevance under explicit modelling assumptions. The framework is demonstrated for indoor air quality by comparing fixed-schedule ventilation and demand-controlled ventilation at different automation levels, with productivity- and health-related effects estimated through literature-based post-processing models. The method combines building performance simulation, stochastic occupancy modelling, scripted control logic, and Sobol sensitivity analysis. In a prototype office, the implemented demand-controlled ventilation reduced occupied-hour CO2 exceedances by 43–53% and fan energy by 25–42%, yielding annual co-benefits of €4.6k–€9.3k. Exploratory sensitivity analysis suggested that occupant activity and infiltration were among most influential parameters, with benefits concentrated in meeting rooms.

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Wen, X., Li, H.

Safe mean-field reinforcement learning for cooperative control of large-scale multi-zone HVAC systems.

Energy and Buildings, Vol. **373**, (2026)

Efficient control of HVAC systems is essential for reducing building energy consumption while maintaining indoor environmental quality. However, in multi-zone scenarios, strong thermal coupling among zones, together with interactions among temperature, CO2 concentration, and humidity, results in highly nonlinear and strongly coupled dynamics, thereby significantly increasing the complexity of control decisions. Furthermore, as the number of zones grows, the joint state–action space expands rapidly, leading to the curse of dimensionality and difficulties in coordinated optimization. Consequently, traditional methods struggle to achieve both scalability and satisfactory control performance. To address these challenges, we develop a dynamic optimization model for multi-zone HVAC systems, where multi-variable coupled control is formulated as a multi-agent decision-making problem, capturing both inter-zone and inter-variable interactions. Building upon this, we propose a Safe Mean-Field TD3 (SMF-TD3) algorithm to enable efficient and scalable cooperative control. Specifically, mean-field theory is introduced to approximate individual interactions via aggregated behaviors, thereby reducing system complexity and enabling scalable decision-making. Meanwhile, to satisfy thermal comfort, air quality, and equipment safety constraints, a Lagrangian-based safe reinforcement learning mechanism is adopted, where constraints are embedded into policy optimization and Lagrange multipliers are adaptively updated to balance performance and constraint satisfaction. Finally, in the seven-day, 12-zone simulation, SMF-TD3 reduces electricity cost by 3.37% relative to CPO and 17.11% relative to MADDPG, and cumulative constraint violations by 75.05% relative to MF-TD3. Across the 12-, 20-, and 30-zone systems, training time is reduced by 52.48%–58.44% relative to MASAC, supporting improved economic performance, constraint satisfaction, and scalability under the tested conditions.

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S, V., Hamaludhin, A. H., D, N., L, B., S, K., B, B.

Smart Indoor Air Quality Monitoring and Selective Air Purification using IoT.

2026 6th International Conference on Soft Computing for Security Applications (ICSCSA)

The purpose of this paper is to design and develop an IoT-based Smart Air Purification System. This smart system consists of three types of sensors: Smoke, Air Quality, and Temperature & Humidity (DHT11). All these sensors are interfaced with an ESP32 microcontroller unit. The dirty air enters the chamber through a DC suction fan and then goes through HEPA filters and water filters before exiting via an exhaust fan. A comparison of the output values obtained at the entry and exit sensors indicates how effective purification is in numerical terms. The real-time data is then sent to the Blynk Internet of Things platform for remote monitoring as well as being shown locally through an LCD display. It can be seen from the results that

harmful gases, smoke, and particulate matter can be effectively removed. Furthermore, this system is more practical and efficient to use indoors.

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A., M. a. V. N. V. K. B. S. K. C. B. K.

Solar-Powered and AI-Integrated Enhanced IoT Air Quality Monitoring System.

2026 International Conference on Smart Systems for Electrical, Electronics, Communication and Computer Engineering (ICSSEECC)

This paper presents a Solar-Powered and AI-Integrated Enhanced IoT Indoor Air Quality Monitoring System designed for continuous environmental surveillance with proactive safety alerts. The proposed system is built around an ESP32 microcontroller integrated with an MQ135 gas sensor and a DHT11 temperature and humidity sensor to monitor harmful gases and climatic conditions in real time. A solar energy unit ensures autonomous and uninterrupted operation, making the system energy-efficient and suitable for long-term deployment. Local alerts are provided using an LCD display, LED indicators, and a buzzer for immediate safety notification. A lightweight Artificial Intelligence (AI) model based on linear regression is embedded to predict hazardous air quality trends before critical thresholds are reached. Real-time data, alerts, and predictive warnings are transmitted to the Blynk mobile application via Wi-Fi for remote monitoring. Experimental results demonstrate reliable gas detection, fast system response, and accurate prediction performance. The proposed system offers a low-cost, intelligent, and sustainable solution for enhancing indoor air safety in industrial, commercial, and residential environments.

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Fermoso, J., Rodríguez-Sufuentes, S., Rodríguez, A., Suárez, S., Diéguez, J., Pérez-Setién, C.*, et al.*

Toward integrated hospital IAQ monitoring.

Atmosphere, Vol. **17**, (2026), p.

Indoor air quality (IAQ) in healthcare environments is affected by dynamic interactions between occupancy, ventilation, operational activities, and indoor emission sources, which are not always captured through conventional punctual assessments. This study evaluated long-term IAQ dynamics in different hospital microenvironments using continuous low-cost sensor monitoring combined with targeted chemical characterization of volatile organic compounds (VOCs) and specific aldehydes.

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Zhang, X., Zhang, X., Liu, G., Wang, L., Wan, M. P., Ng, B. F.

Tracing 3D printing emissions: Micro- and nanoplastic formation and the trade-off of mass-based mitigation.

Journal of Hazardous Materials, Vol. **518**, (2026)

The widespread adoption of fused deposition modeling (FDM) 3D printing introduces undocumented inhalation risks from airborne micro- and nanoplastics (MNPs) in indoor microenvironments. While prior studies have focused on non-specific nanoparticles and volatile organic compounds (VOCs), the precise chemical identity, emission mechanisms, and respiratory fate of printing-emitted MNPs remain critical knowledge gaps. This study systematically quantified MNP emissions across five commercial filament types using size-resolved monitoring, morphological analysis and pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS). Substantial MNP emissions were observed for ASA and ABS filaments (2.3 ± 1.0 and 0.6 ± 0.3 mg kg–1, respectively). Crucially, morphological evidence of droplet condensation combined with chemical characterization revealed that these emitted MNPs predominantly comprised polyethylene (PE) and polyvinyl chloride (PVC) not originating from the parent polymer matrices. Furthermore, respiratory dosimetry modeling unveiled a mitigation trade-off: while standard FDM enclosures removed > 90% of total nanoparticle mass, they selectively allowed ultrafine nanoparticles to

escape, inadvertently driving the pulmonary deposition fraction of inhaled mass from 10.3% to 19.8% in adults, and up to 29.5% in children. These findings highlight that mass-based metrics alone do not fully capture changes in inhalation exposure and respiratory deposition patterns. We advocate for integrating particle number concentrations into indoor air quality standards and requiring disclosure and regulation of all filament constituents to reduce potential MNP exposure at the source.

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Schreiber, L., Schuh, B., Shchegelskiy, K., Wardah, W., Büyüktaş, T. M. K., Möller, S.*, et al.*

Trapped in a Soundproof Box: How CO2 Levels Influence Speech Quality Assessment and Response Behaviour.

Research Square, (2026)

Standardised tests to assess speech quality, such as the listening tests of Recommendation P.800 of the International Telecommunication Union Telecommunication Standardization Sector (ITU-T), require controlled experimental environments to ensure reliable subjective ratings. However, poor ventilation in soundproof booths can lead to increased carbon dioxide (CO2) concentrations, which may affect cognitive function and judgement. This study investigates whether CO2 levels affect speech quality ratings and response behaviour in listening tests. We conducted a classic mean opinion score (MOS) listening experiment while continuously measuring CO2 concentrations in a non-actively ventilated sound booth. Our analysis reveals three key findings: (1) Higher CO2 levels significantly reduce response time, suggesting a shift towards more impulsive decision making. (2) Speech quality ratings are systematically affected, with poorer samples rated more favourably and higher quality samples rated less favourably at elevated CO2 concentrations. (3) Response variability decreases under high CO2 conditions, suggesting reduced sensitivity to quality differences. These findings highlight a previously overlooked factor in speech quality research, suggesting that ambient air quality may introduce bias into subjective ratings. We discuss the implications for experimental design and the need for controlled ventilation in perceptual studies to ensure data validity.

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Huang, C., Kwok, H. H. L., Liu, H., Hou, F., Wu, Z., Cheng, J. C. P.*, et al.*

Uncertainty-aware spatiotemporal indoor air quality prediction with dynamic graph transformers.

Building and Environment, (2026)

Indoor air quality (IAQ) prediction models still mostly produce deterministic forecasts, which limits their value for risk-aware decision-making when forecast reliability matters as much as forecast accuracy. This study proposes the Uncertainty-Aware Indoor Air Quality (UA-IAQ) framework, which combines learned feature gating with an Uncertainty-Quantified SpatioTemporal Dynamic Graph Transformer (UQ-STDGFormer). The gating module reweights noisy and redundant IoT inputs, while the transformer addresses rigid sensor relationships and isolated contextual covariates. UQ-STDGFormer uses a reproducible Pearson-correlation -nearest-neighbour graph with fixed binary topology and dynamically updated edge-aware attention, integrating occupancy, calendar, meteorological, and outdoor air-quality context. Deep Ensemble Learning is used to estimate both aleatoric and epistemic uncertainty. Validation on a one-year campus-library dataset shows MAE reductions of 15.7% and 34.0% relative to the best baselines at 3 and 6 hours, respectively; the 1-hour reduction is 2.6% and is interpreted as competitive. Prediction-interval coverage probabilities are 96.90%, 94.56%, and 89.78% at 1, 3, and 6 hours, revealing reduced calibration at the longest horizon. Repeated-run ablation at the 12-hour stress-test horizon most strongly supports external context and explicit hybrid context nodes, while the smaller effects of feature gating, ensembling, and iterative edge refinement remain inconclusive across three outer seeds. Context-importance and hotspot analyses identify influential temporal and outdoor variables and location-specific uncertainty patterns. Overall, the framework improves longer-horizon robustness and supports uncertainty-aware sensor deployment and risk-aware building management.

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Xinshuai, G., Chang, S., Dahai, Q.

Ventilation Performance Evaluation for a Long-Term Care Facility Room Based on CFD Simulations.

Proceedings of eSim 2026: 14th Conference of IBPSA-Canada

Residents in long-term care (LTC) facilities are particularly vulnerable to indoor air pollution due to their age, limited mobility and the high proportion of time they spend indoors. Particulate matter (PM) emissions from indoor sources, such as printers, can compromise the indoor air quality and increasing exposure risks. This study aims to optimize the ventilation design in a typical LTC room to reduce PM exposure from a printer. An orthogonal experimental design approach was applied to design the CFD simulation cases for evaluating the effect of air change rate (ACH), air supply direction and position on indoor airflow patterns and pollutant dispersion. The results indicate that the ACH is the most influential factor in improving indoor air quality and PM removal efficiency. The optimal configuration, when the inlet positioned the on the side wall of the room, a velocity of 1.30 m/s, and airflow direction 30° downward, yields the lowest average PM concentration (0.0211/m3). A subsequently health risk assessment confirms that this optimized inlet configuration significantly reduces PM exposure levels for elderly occupants. This research provides valuable insights for improving ventilation design in long-term care facilities, contributing to the development of healthier indoor environments for elderly populations.

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Kapusta, W., Walerzak, M., Sołtyk, A., Ponto-Wolska, M., Winiarski, A., Wagner, L.*, et al.*

Volatile Organic Compound Emissions and Human Odor Perception of Dental 3D-Printing Photopolymer Resins.

In: Materials. 2026. pp. 3818.

The increasing use of photopolymer resins in dental three-dimensional (3D) printing has raised concerns regarding occupational exposure to volatile organic compounds (VOCs). This study aimed to characterize and compare formaldehyde (HCHO) and total volatile organic compound (TVOC) emission profiles of five commercially available dental 3D-printing resins and to explore their relationship with subjective odor perception. Subjective odor perception was assessed during routine educational laboratory activities using a numerical rating scale (0–10). Time-resolved HCHO and TVOC measurements were subsequently performed under standardized chamber conditions using a portable air-quality monitor, with three consecutive 10 min measurement cycles conducted for each resin using the same standardized 200 mL sample. Two participants reporting upper respiratory tract infection symptoms were excluded, resulting in a final sensory sample of 50 participants. Perceived odor intensity differed significantly among the tested resins (Friedman test, $\chi2(4) = 55.54$, $p < 0.001$; Kendall's $W = 0.278$). A positive resin-level association was observed between mean odor intensity and TVOC concentration at the 10 min endpoint of the first post-agitation measurement cycle (Spearman's $\rho = 0.70$); however, this relationship was not statistically significant in the exact two-sided permutation analysis ($p = 0.233$) and was considered exploratory. HCHO–odor correlation analysis was not performed because HCHO concentrations for three of the five resins exceeded the upper measurement range of the instrument. Notably, a plant-based resin exhibited relatively high odor intensity despite comparatively low TVOC emissions, suggesting that total emission magnitude alone may not fully explain odor perception. The tested dental photopolymer resins exhibited distinct material-dependent emission and odor-perception characteristics. Odor perception should therefore be considered complementary to, rather than a substitute for, instrumental emission characterization. Integrating sensory assessment with instrumental emission measurements may support a more comprehensive evaluation of dental photopolymer resins and inform future occupational-safety studies.

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Taparia, N.

What CO2 Tells Us about Crowds: Lessons from Continuous Monitoring in a Multi-Use Arena.

2026 ASHRAE Annual Conference. June 27- July 1, 2026 | Austin, TX

This paper presents an analysis of CO_2 measurements collected from a building automation system (BAS) in a large, enclosed, multiuse arena with a capacity of approximately 17,000 people for sporting events and 19,000 people for concerts. This facility was equipped with a network of nondispersive infrared (NDIR) CO_2 sensors located in seating areas, concourses, and concession areas. To our knowledge, this study represents the first dataset characterizing CO_2 levels in such a facility for various events. Data from these NDIR ????2 sensors were collected over a 2-year period (2019 - 2020) acrossnumerous events with varying durations and attendance profiles. We performed statistical analyses to determine the significance of observed differences between events and operational conditions.

Results reveal distinct CO_2 dynamics across event categories. Concerts typically produced faster decay rates than sporting events, reflecting differences in activity patterns and occupant movement. Spatial comparisons indicated imperfect air mixing, with elevated CO_2 levels in concession areas during intermissions and elevated CO_2 levels in exit areas after an event ended. Temporal analyses revealed that CO_2 concentrations closely tracked crowd inflow and outflow, providing a proxy for real-time occupancy.

The findings demonstrate that continuous CO_2 monitoring offers a powerful diagnostic tool for evaluating IAQ and managing ventilation in large public venues. Insights from this work support enhanced demand-controlled ventilation strategies that improve occupant health protection, operational efficiency, and compliance with IAQ and energy performance standards.

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