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

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Google Scholar, Lens et WoS

Arbi, H., Irwan, H.

Analysis of Factors Causing Decrease In Heating, Ventilation, and Air Conditioning (HVAC) Performance Using A Cause Effect Diagram (Fishbone Diagram).

International Journal of Science and Environment (IJSE), Vol. **6** n°(3), (2026), 56-65 p.

The Heating, Ventilation, and Air Conditioning (HVAC) system is a supporting facility that functions to regulate temperature, humidity, air circulation, and indoor air quality to ensure smooth production processes. A decline in HVAC system performance can increase energy consumption, extend downtime, and reduce overall operational effectiveness. This study aims to identify the factors causing the decline in HVAC performance using the Cause-and-Effect Diagram (Fishbone Diagram). The research was conducted on the Air Handling Unit (AHU) at PT XYZ Batam using maintenance and failure data collected from January to December 2025. The research methods included field observations, documentation, and analysis based on the 6M approach, consisting of Man, Machine, Method, Material, Measurement, and Environment. The results showed a total of 61 failure incidents, with the most dominant failure being dirty air filters accounting for 18 cases (29.51%), followed by dirty cooling coils with 12 cases (19.67%), and worn blower belts with 9 cases (14.75%). The Fishbone Diagram analysis indicated that the Machine and Method factors were the primary causes of HVAC performance degradation, mainly due to dirty filters, contaminated cooling coils, and ineffective preventive maintenance practices. The proposed improvements include routine component cleaning, scheduled preventive maintenance, regular calibration of measuring instruments, the use of standard compliant spare parts, and technical training for maintenance personnel. Implementing these recommendations is expected to improve HVAC system reliability, reduce failure frequency, enhance energy efficiency, and support sustainable industrial operations.

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Prince, Yoon, B., Kumar, P.

Artificial Intelligence-Based Optimization of HVAC Systems: Advances in Thermal Comfort, Energy Efficiency, Energy Consumption, Challenges, and Research Gaps.

Energy, (2026)

As buildings consume roughly a third of all the energy used in the world, improving their energy efficiency and environment-friendliness is essential. Artificial intelligence (AI) methods, especially machine learning and deep learning, have been gradually adopted over the last decade to handle the complexity of built-environment systems. This review summarizes the recent research on AI-driven integrated and holistic frameworks for building management. Functions such as occupancy detection and behavior modeling, energy consumption forecasting and optimization, indoor air quality and thermal comfort assessment, and fault detection and diagnosis must be examined to streamline the management of buildings and address interrelated heating, ventilation, and air-conditioning issues. While studies have evaluated the performance, modeling approaches, and methodological structures of AI-based techniques, identifying viable AI models remains challenging due to the rapid proliferation of algorithms across spatial scales, including system components, urban-level studies, temporal resolutions, and assessment metrics. Because of this methodological diversity, drawing direct comparisons and selecting optimal techniques for specific applications is difficult. Although AI techniques can improve the energy efficiency of buildings, most studies have focused on controlled laboratory settings or simulations, with few post-occupancy evaluations and real-world deployments. Standardized evaluation frameworks and practical guidelines are required to implement AI solutions in operational buildings. Based on the current study, from 2000 to 2026, the application of AI techniques and thermal comfort models has enabled energy saving on average 21.91 and 44.76 % and comfort improvement on average between 21.77 and 85.95 %. Finally, this paper discusses the challenges faced in the use of AI for energy productivity and comfort improvement and opens main future directions in relation with AI-based HVAC control systems for human comfort and energy-efficiency management.

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Delater, A., Fable, S., Berthelot, B., Raventos, C., Queron, J., Coll, I.*, et al.*

Assessment of cabin filtration efficiency: contribution to an on-road methodology.

Aerosol Research Discussions, Vol. **2026**, (2026), 1-23 p.

The use of cabin filters provides protection for passengers against outdoor pollution caused by particles (aerosols) when travelling by car. Their filtration efficiency is assessed through rigorous laboratory studies in accordance with standards.However, there are few or no comparable studies conducted under real road conditions using reference particle measurements to complement the laboratory results. In this context, our study aims to contribute to the improvement of on-road aerosolmeasurement by evaluating cabin filters with gravimetric measurements. To this end, a sampling line upstream of the cabinfilter in an area located under the windscreen, and a sampling point downstream of the cabin filter on the front seat inside thecabin were designed. The sampling efficiency of the sampling line was calculated using a transdisciplinary work involvingComputational Fluid Dynamics, wind tunnel measurements and numerical methods. The results showed that its sampling efficiency for PM1 and PM2.5 (i.e., particles with an aerodynamic diameter less than 1 and 2.5 µm, respectively) is greater than 94 and 77 %, respectively. Next, on road tests were carried out in a moving car in the Paris region, for two different cabinfilters and during tests without a cabin filter. The average filtration efficiency was 51.4 % (n=15), 52.7 % (n=14) and 9.5 %(n=4) for PM1 and 57.3 % (n=9), 56 % (n=9) and 32 % (n=4) for PM2.5, respectively, for Filter A, Filter B and without a cabinfilter. Lastly, optical counters were simultaneously operated with gravimetric measurements. The results showed that optical counters underestimate the concentration of PM2.5, highlighting the importance of using a reference method to measure theparticles under real road conditions.

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Guerrero Ramírez, K., Pachano, J. E., Santamaría Ulecia, J. M., Fernández Bandera, C.

Calibration as Diagnosis (CaD): A proof of concept for a physics-based framework for fault detection and diagnosis in building systems.

Energy and Buildings, Vol. **370**, (2026)

Conventional fault detection and diagnosis (FDD) methods in buildings primarily rely on sensor alarms or data-driven pattern recognition, which often lack physical interpretability and although they may identify a fault, they often struggle to determine its location or underlying cause. Existing FDD and commissioning approaches typically employ calibrated white-box models as comparative references or dynamic baselines for residual monitoring. However, model calibration is treated as a preparatory step aimed at improving predictive accuracy, rather than as part of the diagnostic framework. This paper introduces Calibration as Diagnosis (CaD), a proof-of-concept framework that reframes the calibration process as an integral component of FDD. Rather than using calibration solely to improve model fidelity, CaD interprets systematic deviations in physically meaningful calibrated parameters as indicators of operational faults and building performance deficiencies. This CaD framework is demonstrated in a non-residential building conditioned by an air-based Heating, Ventilation and Air-Conditioning (HVAC) system. Four calibration formulations are tested, ranging from a single-step simplified HVAC, single-objective temperature-focused approach (Model A), to single-step simplified HVAC multi-objective thermo-energetic (Model B) and hygrothermal-energetic (Model C) approaches, and finally a two-step detailed HVAC hygrothermal-energetic formulation (Model D). Despite differences in objective functions, HVAC representation, calibration period, and predictive capability, all formulations converged towards a consistent diagnostic interpretation. The inferred ventilation shortfall exceeded 75% relative to the design requirements. Furthermore, the subsequent on-site inspection identified an architectural configuration consistent with the inferred diagnosis and representing the most plausible explanation for the inferred ventilation deficiency, revealing a building design flaw that would have been difficult to identify through conventional sensor-based diagnostics alone because the building's low occupancy kept indoor CO2 concentrations within recommended limits. By elevating calibration from a preprocessing task to a diagnostic observable, the proposed CaD approach offers a physics-based pathway for fault detection, commissioning and building auditing under realistic monitoring conditions. Although further validation is required, these results suggest that calibration-derived parameters can act as physically interpretable fault indicators, enabling quantitative auditing without additional airflow instrumentation.

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Idrissi, A., El Mghari, H., El Amraoui, R.

CFD investigation of ventilation effectiveness and thermo-hydraulic performance in mixed, displacement, and reversed ventilation systems.

Energy and Buildings, Vol. **369**, (2026)

This study presents a computational fluid dynamics (CFD) investigation of ventilation performance in a full-scale room under mixed ventilation (MV), displacement ventilation (DV), and reversed mixed ventilation (RMV) configurations. The CFD model was validated against published experimental measurements of temperature and velocity. Ventilation performance was assessed using air change efficiency (ACE), mean age of air (MAA), and pressure drop. The results show that DV provides the best overall performance, achieving the highest ACE (51.01%) and the lowest MAA (1775.71 s), indicating more effective air renewal within the occupied zone. MV exhibited intermediate performance (ACE = 43.85%, MAA = 2109.33 s), whereas RMV showed the lowest ventilation effectiveness (ACE = 41.88%, MAA = 2208.56 s) due to the formation of recirculation zones that increased air residence time. DV also produced the lowest pressure drop (18 Pa), compared with 25 Pa for MV and 28 Pa for RMV. The findings demonstrate that displacement ventilation offers superior ventilation effectiveness and airflow organization under the investigated conditions, highlighting the importance of ventilation configuration and airflow distribution for ventilation effectiveness.

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Stinson, B. W., Lei, E., Gall, E. T.

Characterizing Indoor Surface VOC Contamination After the 2025 Los Angeles Fires and the Protective Role of Air Cleaning.

Environmental Science & Technology Letters, (2026)

We quantify volatile organic compound (VOC) emissions from indoor surface swabs and portable air cleaner (PAC) filters collected in a home 30 days after the 2025 Los Angeles wildland-urban interface (WUI) fires. We calculate emissions for 17 fire-relevant compounds. Surface emissions exceeded those of clean controls, and emissions from a windowsill in a room without a PAC were ∼15× and ∼2× higher for benzene and toluene, respectively, than rates reported in the literature for comparable materials unaffected by smoke/soot. Particle filters installed in PACs at the start of the fire emitted aromatics at rates comparable to those reported in a study where filters operated for 200 days in a city. Emissions from activated carbon filters exceeded those of the particle filters tested as part of the present study by >3×. A windowsill in a room without a PAC off-gassed more VOC mass than a windowsill in a room with a PAC, suggesting that air cleaners can reduce surface contamination. Modeling with benzene emission rates from impacted surfaces in a hypothetical indoor space resulted in a predicted indoor concentration ∼6× greater than outdoors. This study shows surfaces act as persistent VOC sources following WUI fires and indicates indoor surfaces affect exposure during and after fire events.

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Jannat, A., Campion, R., Phillips, A., Goncalves Da Costa, B., Manriquez, D.

Concentration of volatile organic compounds within indoor dairy facilities.

Journal of Environmental Quality, Vol. **55** n°(4), (2026)

Abstract Volatile organic compounds (VOCs) are important components of indoor air quality in dairy production systems, yet information on their spatial distribution and dominant compounds within enclosed barns and milking parlors remains limited. This study aimed to characterize VOC profiles and quantify concentrations across indoor locations in commercial dairy facilities operating under different housing and ventilation configurations. Air samples were collected from cow housing barns and milking parlors at two commercial dairies in Weld County, Colorado, including a mechanically tunnel-ventilated barn with a rotary milking parlor (Farm A) and a naturally ventilated barn with an automated milking system (Farm B). Weekly integrated air samples were obtained using evacuated 6-L stainless steel canisters deployed for a 7-day sampling period. Canisters were positioned at three locations within each barn and at the center of each milking parlor, while temperature, relative humidity, and wind speed were recorded simultaneously. A total of 52 VOC species were consistently detected across both dairies. Gas measurements in the barns were averaged by location and ranked by concentration to represent overall conditions. Methane, ethane, and propane were the most abundant compounds in both farms? barns and milking parlors. Hydrocarbons, including n-butane, n-pentane, and i-butane, as well as acetonitrile, were consistently detected but varied in relative ranking across locations. Spatial variability within barns revealed distinct concentration patterns associated with sampling position. These findings provide characterization of VOC composition in indoor dairy environments and highlight the importance of spatial sampling for identifying dominant compounds, which might help to improve air quality.

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Zhu, Y., Liang, W.

Definition of Standard Office Environments in China for Evaluating the Impact of Volatile Organic Emissions from Building Material.

2nd International Conference on Building and Simulation-BAS. Borlaenge, Sweden. 02-04 jul. 2025

This study develops standardized room models for Chinese office environments to bridge the gap between laboratory-based and field-based VOC emission assessments. By analysing architectural drawings of 22 office buildings, we quantified parameters for 141 private offices and 106 meeting rooms. The median-based model defines standard offices (14.4 m2 floor area, 2.8 m height) with 1.056 m2/m3 furniture loading rates and meeting rooms (41.8 m2, 2.8 m height) at 0.882 m2/m3. Chinese private offices demonstrate a 43% higher furniture loading density compared to BIFMA standards, reflecting more compact spatial configurations. These region-specific models account for discrepancies in material density and usage patterns, thereby enabling precise conversions from emissions to exposure levels for regulatory compliance and effective indoor air quality (IAQ) management.

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Yaddarabullah, Y., Faruq, U. A.

Deployment of a Machine Learning Based Indoor Air Quality Predictor on NodeMCU ESP32 Using EloquentTinyML.

JISA(Jurnal Informatika dan Sains); Vol 9, No 1 (2026)

Indoor air quality monitoring increasingly requires local intelligence because indoor exposure conditions can change faster than centralized systems can respond. However, many machine learning based indoor air quality predictors remain difficult to deploy on microcontrollers due to memory limits, computation constraints, network dependence, and the lack of a reproducible edge deployment workflow. This study develops an end-to-end TinyML framework for deploying a lightweight indoor air quality predictor on a

NodeMCU ESP32 using EloquentTinyML and TensorFlow Lite Micro. A synthetic IAQ dataset was generated from eight environmental variables, namely temperature, humidity, PM2.5, PM10, NO2, SO2, CO, and room type, and the indoor air quality score was derived from pollutant weighted features before balancing comfort labels using SMOTE. The proposed compact MLP contains eight inputs, one hidden layer with twelve neurons, ReLU activation, dropout regularization, and a single regression output. Five-fold validation produced an average root mean square error of 5.794, mean absolute error of 4.394, and R 2 of 0.877, while the converted model required only 121 trainable parameters. These results indicate that compact TinyML deployment can provide a feasible proof-of-concept for local indoor air quality estimation, although physical sensor validation remains necessary.

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Hammami, M., Souifi, J., Ghribi, M., Colin, S., Souifi, H.

Design and implementation of an IoT-Based air treatment Single-Room Ventilation System using ESP-NOW.

2025 11th International Conference on Control, Decision and Information Technologies (CoDIT)

Growing concerns about both indoor and outdoor air pollution have highlighted the vital importance of Indoor Air Quality (IAQ), an issue amplified by recent lifestyle changes, including those arising from the COVID-19 pandemic. Although traditional ventilation systems still widely used, they present several limitations including their maintenance and cost as well as their inability to fully eliminate pollutants.This paper presents the design approach of an IoT-based Single Room Ventilation System. This system is dedicated to operating autonomously or as part of a networked system alongside other ventilation units within the same building.To ensure reliable communication between units, the ESP-NOW communication protocol was used. Moreover, a mobile application was developed and implemented using Dart and Flutter software enables users to monitor and control the system remotely. A database and IoT-based platform are used to collect and log real time parameters. This proposed solution aims to enhance IAQ management via user-friendly interface, accessible through both Android and iOS devices.

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Borges, A. D. S., Oliveira, M.

Design and validation of a reliable, low-cost IoT decision support system for proactive indoor air quality management.

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

Indoor Air Quality has emerged as a critical determinant of health, productivity, and building performance, particularly as people spend over 90 % of their time indoors. Continuous Indoor Air Quality monitoring is essential for preventing Sick Building Syndrome and optimizing HVAC energy consumption, yet the high cost and demanding calibration of reference-grade instruments hinder their large-scale deployment. This study presents MiQar, a low-cost, scalable IoT-based Decision Support System for real-time Indoor Air Quality-driven HVAC optimization in smart buildings. MiQar integrates heterogeneous Commercial Off-The-Shelf sensors for CO2, Total Volatile Organic Compounds, temperature, and humidity within a three-tier IoT architecture. The core innovation of MiQar is a multi-sensor redundancy mechanism that ensures cross-validation between sensors with different measurement principles, thus significantly enhancing data reliability without requiring complex, costly pre-deployment calibration. Laboratory benchmarking against an Aeroqual Series 500 reference confirmed low maximum deviations within ±38 ppm (CO2,eq) and ±32 ppb (Total Volatile Organic Compounds). Furthermore, field validation in a controlled pilot environment (university facility) demonstrated strong correlation R2 = 0.86 for CO2,eq; R2 = 0.73 for Total Volatile Organic Compounds) and reliable trend tracking under dynamic occupancy conditions. The rule-based Decision Support System effectively converted this validated data into proactive ventilation and maintenance actions, demonstrating MiQar's potential to significantly enhance Indoor Air Quality management rigor and promote energy efficiency in smart building environments.

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Freitag, L. L.

Development and Validation of a Predictive Mathematical Model for Cognitive Performance and Occupational Stress Based on Indoor Air Quality: A Low-Cost Implementation Using Embedded Systems.

Research Square, (2026)

Indoor air quality (IAQ) is a critical determinant of cognitive performance and psychological well-being in occupational environments, yet accessiblepredictive tools that translate sensor data into quantifiable psychological impactmetrics remain scarce. This study develops and validates a mathematical modelfor real-time assessment of cognitive efficiency and occupational stress basedon IAQ parameters. Methods: The proposed model integrates thermodynamic,physiological, and psychological variables into a composite degradation index(Ideg) that drives sigmoid transfer functions for cognitive efficiency (Pcon) andpsychophysiological stress (Iestresse). Key components include the Oxygen Dis-placement Hypoxia Factor (fO2), the Hyperventilation Metabolic Rate (Mmet),and the Organic Clearance Constant (λwash). The model was implementedin firmware for the ESP32 microcontroller with ENS160 (eCO2, TVOC) andBME280 (temperature, humidity, pressure) sensors, generating real-time envi-ronmental reports with future predictions via an embedded web server. Results:Cross-validation against four independent international studies yielded a rootmean square error of 0.18 percentage points and maximum absolute error of 0.22percentage points. Experimental deployment in a 120 m3 office with 10 occupants over an 8-hour workday demonstrated the system's ability to track cognitivedegradation from 98.2% efficiency at 08:00 to 62.4% at 14:00, with 4-hour pro-jections alerting managers to impending critical stress levels. Conclusion: Theproposed system enables continuous, low-cost IAQ monitoring with quantitative1predictive assessment of psychological impact, providing a practical tool for pre-ventive occupational health management at a total component cost under USD30.

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Seyedrezaei, M., Becerik-Gerber, B., Lucas, G., Roll, S. C., Narayanan, S.

Environmental Comfort in Hybrid Work: A Longitudinal Preliminary Field Study of Home and Office Workspaces.

This study examines environmental comfort differences between home and office workspaces and their associations with productivity and well-being among 19 knowledge workers monitored over four months via ecological momentary assessments. Participants rated comfort across four domains (lighting, temperature, air quality, noise) and reported productivity, mood, stress, and stress states four times daily. Mixed-effects models indicated domain-specific patterns: offices showed higher comfort for lighting (OR=0.56) and noise (OR=0.48), while temperature showed individual heterogeneity. Lighting and temperature comfort were positively associated with productivity (4.3% and 2.4% increase per comfort level), while comfort showed weak associations with mood and stress. Bayesian multinomial models suggested that higher comfort was associated with lower odds of boredom (ORs=0.40-0.56). Substantial between-person heterogeneity was observed in the direction and magnitude of home-office differences in comfort, well-being, and productivity, suggesting that hybrid policies may not be one-size-fits-all and may benefit from greater flexibility, though these findings should be interpreted as exploratory.

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Ghaith, A., Rayan, R., Doya, A., Manal, A., Mona, F.-a.-F.

Evaluating the HVAC System Design for Operating Rooms in Nalut Central Hospital According to International Standards.

Al-Farooq Journal of Sciences, Vol. **2** n°(3), pp. 1216-1224

This research aims to evaluate the Heating, Ventilation, and Air Conditioning (HVAC) system in the operating theaters of Nalut Central Hospital and analyze its compliance with approved international standards such as ASHRAE Standard 170 and WHO Guidelines for Surgery. The study adopted a comprehensive analytical approach, combining field visits, technical records review, and direct interviews with staff to assess the system's performance and adherence to modern operating room requirements. The findings revealed that the previously used non-centralized HVAC system had significantly exceeded its recommended operational lifespan. It failed to achieve essential requirements, including positive pressure, standard Air Change Rates (ACH), or precise temperature/humidity control. Currently, the hospital relies on household air conditioners (Split Units) and natural ventilation, which are entirely incompatible with surgical requirements, posing a significant risk of Surgical Site Infections (SSI). The study concluded that the current system is unable to meet standard specifications, necessitating immediate corrective actions, including the installation of a compliant centralized HVAC system.

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Wang, Y.-F., Le, T.-C., Wang, J., Dai, Y.-T., Tran, P.-U., Tran, V.-N.*, et al.*

Exposure-informed ventilation control for nanoparticle pollutants in an enclosed industrial built environment: A laser metal deposition case study.

Building and Environment, Vol. **303**, (2026)

Advanced metal additive manufacturing systems, such as robotic laser metal deposition (LMD), are emerging as localized nanoparticle sources in enclosed industrial built environments. However, the coupled effects of emission dynamics, airflow non-uniformity, and ventilation effectiveness on nanoparticle persistence remain insufficiently understood. This study investigated indoor nanoparticle dynamics and post-process decay in an enclosed robotic LMD chamber by integrating multi-metric aerosol measurements, size-resolved metal analysis, respiratory deposition modeling, and ventilation decay analysis. The 5-min LMD process produced trimodal particle number and mass distributions dominated by nanoparticles, with peak number concentrations reaching 3.46 × 106 #/cm3, nearly three orders of magnitude above background levels. Although the chamber was designed for 100 air changes per hour (ACH), measured post-process decay showed that nominal ACH substantially overestimated the effective nanoparticle decay rate under the tested chamber conditions. Air velocity mapping revealed low-velocity and recirculation regions near the robotic arm and worktable, causing delayed nanoparticle decay. A revised mass-balance model incorporating a chamber-specific mixing efficiency factor estimated that approximately 27% of the nominal ventilation capacity effectively contributed to nanoparticle decay under the tested conditions. Based on nanoparticle number concentration as the most conservative clearance endpoint, a case-specific minimum post-process ventilation time of 13 min was required for concentrations to return to background before worker re-entry, more than four times the current 3-min practice. Respiratory deposition and toxic metal risk analysis further confirmed the need for exposure-informed ventilation control. Overall, this work provides a scalable, building-science-based framework for evaluating ventilation effectiveness and optimizing control strategies for engineered nanoparticle sources in enclosed industrial environments.

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Long, T., Mei, D., Qin, S., Li, Y.

Fast design of buoyancy-driven ventilation openings for multi-story buildings with shared shaft using analytical solutions.

iScience, Vol. **29** n°(8), (2026)

Summary Buoyancy-driven ventilation in multi-story buildings with shared shafts exhibits uneven effects across different stories. This study simplified Acred’s dimensionless design approach into user-friendly analytical solutions to balance the uneven effects. When openings are designed using the proposed analytical solutions, each story achieves close thermal comfort temperatures. The influence of key parameters in the analytical solutions and three application constraints was analyzed. The results show that when the total number of stories N increases from 1 to 25, the average shaft enhancement parameter increases from 1.00 to 2.27. As the top-story shaft enhancement parameter (EN, a design value) increases, the maximum total number of stories (Nmax) to which this method can be applied decreases sharply.

Furthermore, near EN = 1.24, the governing constraint transitions from shaft roof area to critical area for bidirectional flow. The temperature gradient within the shaft leads to an approximately 11% deviation in practical performance.

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Han, B., Hong, K., Lee, G., Kim, J., Koo, J.

[Field-informed reinforcement learning for multi-objective indoor air quality control in naturally ventilated buildings.]()

Building and Environment, Vol. **304**, (2026)

Indoor air quality (IAQ) control in naturally ventilated buildings involves a trade-off between ventilation-driven carbon dioxide (CO2) reduction and particulate matter (PM2.5) infiltration from outdoor environments. This study proposes a physically consistent control framework integrating a physics-informed neural network (PINN) surrogate environment with deep reinforcement learning (DRL) for multi-objective IAQ management under stochastic field conditions. The surrogate environment was constructed from long-term measurements in an occupied office, capturing site-specific pollutant dynamics, occupant behavior, and meteorological conditions. A DRL agent then derived Pareto-optimal policies coordinating natural ventilation and air purification under practical constraints. Multi-seed uncertainty analysis evaluated policy robustness, and SHapley Additive exPlanations (SHAP) interpreted decision mechanisms. During a 30-day validation period, Pareto policies outperformed measured operation and rule-based baselines. The ventilation-oriented policy eliminated CO2 violations and reduced mean CO2 from 776 to 619 ppm, while the purification-oriented policy reduced PM2.5 violations from 1063 to 83 and mean PM2.5 from 17.1 to 6.3 µ g/m3. Simple baselines remained constrained by the CO2–PM2.5 trade-off: ventilation-only control still produced 902 PM2.5 violations, whereas rule-based CO2–PM2.5 control produced 495 CO2 and 267 PM2.5 violations. In contrast, the intermediate RL-derived Policy 14 achieved 70 CO2 and 152 PM2.5 violations. These results demonstrate that physically informed, data-driven control can bridge simulation-based optimization and real-world building operation, providing an interpretable decision-support framework for IAQ management. Its scalability should be interpreted at the methodological-workflow level rather than as direct transferability of the quantitative results or calibrated model parameters.

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Silva, J. D. C., Oliveira Junior, C. a. D. C., Santos, F. a. C. D., Santos, C. S. D., Pereira, J. L., Sales, A. D.

[Gestão inteligente da qualidade do ar interno: uma abordagem orientada a registros estruturados. (Gestion intelligente de la qualité de l'air intérieur : approche fondée sur des enregistrements structurés)]()

Revista Projeção e Docência, Vol. **17** n°(4), (2026)

O objetivo deste estudo foi desenvolver e validar o aplicativo móvel Air Watch, para ser uma solução inovadora, de monitoramento e gestão da qualidade do ar interno em ambiente hospitalar climatizado artificialmente. A concepção do software ocorreu em quatro etapas: planejamento, desenvolvimento, criação do aplicativo e testes verificação e usabilidade do Air Watch com uso do método System Usability Scale. O software com acesso à internet permite identificar a geolocalização da atividade, realizar o registro estruturado digital manual dos dados, efetuar o cálculo automático dos padrões referenciais da Associação Brasileira de Normas Técnica 17037, registrar fotos do ambiente, viabilizar o armazenamento do laudo consolidado, sinalizar alertas de conformidade e não conformidade, apresentar graficamente os valores coletados e gerar relatório de medição por setor, instituição e períodos. Os resultados dos testes de análise técnica e de usabilidade para o protótipo obteve média final de 90 pontos em uma escala de 100 possíveis. Conclui-se que o aplicativo configura-se como uma solução móvel eficaz para o registro estruturado no monitoramento ambiental e controle da qualidade do ar, potencializando ações preventivas e corretivas.

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García-Monge Rábanos, M., Zalba Nonay, B., Guillén-Lambea, S.

Health and energy efficiency: uncertainties in the calculation of ventilation flow rates and design criteria in building renovation.

Jornada de Jóvenes Investigadores del I3A, Vol. **14**, (2026)

In the current context of building retrofits and decarbonization, energy efficiency cannot be considered independent of health. This article analyses the uncertainties involved in calculating ventilation rates according to standards such as EN 16798-1 and demonstrates the need for high rates, adjusted according to indoor air quality levels.

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Liang, B., Yun, T., Song, Y., Wang, L., Zhou, Z., Mo, H., *et al.*

Health risk assessment-based indoor VOC thresholds for newly renovated environments in Chongqing, China: The necessity for stricter standards.

Atmospheric Pollution Research, Vol. **17** n°(8), (2026)

Exposure to indoor volatile organic compounds (VOCs) is associated with adverse health effects, yet few studies have systematically bridged health risk assessment and regulatory compliance evaluation. This study measured formaldehyde, benzene, toluene, xylene, and total VOCs in newly renovated residences, offices, and public places (schools and hospitals) in urban Chongqing, southwest China. According to current national standards, 57.8% of rooms exceeded concentration limits, primarily due to formaldehyde (averaged at 0.092 mg/m3). However, cancer risk assessment revealed that formaldehyde exceeded the significant risk threshold (1×10^{-6}) in 100% of residences and 71.9% of public places, far above their respective concentration-based exceedance rates (55.8% and 61.1%). This critical disconnect between regulatory compliance and actual health risk highlights the inadequacy of current standards. Non-cancer hazard quotients also indicated potential concern in all residences. Children's rooms were identified as priority control areas. Health-based exposure limits derived from risk criteria were lowest for residences. Notably, those for benzene and formaldehyde in residences were lower than the current Chinese national standard limits, indicating that stricter, health-oriented standards are warranted. The findings of this study provide key input data for subsequent assessments of the disease burden attributable to indoor VOC exposure and offer scientific support for the potential update of health-based indoor air quality standards in China.

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Fatahian, E., Awwal, S., Mishra, R., Fleming, L., Fatahian, H.

Healthy and energy-efficient building retrofits: A systematic review of CFD, digital twins, and occupant-centred intelligence.

Building and Environment, Vol. **304**, (2026)

Building retrofits are essential for reducing carbon emissions, improving energy efficiency, and upgrading ageing building stocks. However, interventions such as insulation, airtightness improvement, glazing replacement, and HVAC modernisation can also modify airflow, pollutant transport, thermal comfort, moisture balance, overheating risk, and occupant health. This systematic review examines the role of Computational Fluid Dynamics (CFD), Digital Twins (DTs), occupant behaviour modelling, and machine learning in supporting intelligent, health-centred retrofit strategies. Using a PRISMA-informed methodology, studies applying CFD, DTs, or hybrid approaches to retrofit performance assessment were synthesised. The findings show that conventional energy models are useful for estimating annual energy demand but often fail to capture local airflow patterns, contaminant hotspots, thermal stratification, ventilation effectiveness, and occupant exposure risks. CFD provides detailed insight into airflow, heat transfer, pollutant dispersion, moisture transport, ventilation performance, and airborne infection transmission. Occupant behaviour, including walking, window opening, door use, and occupancy schedules, strongly influences airflow and contaminant pathways, especially in airtight retrofitted buildings. DTs further enhance retrofit assessment by integrating sensor data, predictive simulation, and adaptive control for continuous performance optimisation. Machine learning methods are increasingly used to accelerate CFD predictions, reconstruct indoor environmental fields, and support near-real-time decision-making. Although retrofits can improve winter comfort and reduce heating demand, they may also increase overheating, CO_2 concentrations, VOC accumulation, moisture-related problems, and infection vulnerability when ventilation is inadequate. To address these trade-offs, this review proposes a Retrofit Suitability Index (RSI) integrating energy efficiency, indoor air quality, thermal comfort, health protection, affordability, and user acceptance for healthier, resilient, occupant-centred retrofits.

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Zhou, X., Tong, J., Fang, W., Zhu, J., Song, C., Wang, Y.*, et al.*

High-throughput prediction of fabric-air partition and diffusion coefficients for indoor organic compounds: A QSPR modeling framework.

Journal of Hazardous Materials, Vol. **515**, (2026)

Fabric materials serve as both significant sinks and secondary emission sources for organic pollutants in indoor environments. Accurately determining their mass-transfer parameters is essential for assessing indoor pollutant fate and exposure risk. However, existing measurement methods are time-consuming and costly, and available predictive models are limited to single parameters, constraining prediction efficiency and accuracy. This study develops a dual-parameter QSPR framework for the unified prediction of the apparent diffusion coefficient (Dm) and fabric–air partition coefficient (Kfa) of organic compounds in indoor fabrics. By embedding porous-media mass-transfer mechanisms into the model structure and replacing experimentally determined material parameters with DFT-derived electronic descriptors, most model inputs become computable from molecular. This makes the framework free of any compound-specific fabric sorption measurements. The reliability of the dual-parameter framework is confirmed through internal and external validation against literature data and independent sandwich chamber experiments. Both models achieve R2adj and Q2LOO above 0.94, with chamber-validation residuals within ±1. This study substantially improves prediction efficiency, supporting high-throughput screening of indoor organic pollutant fate, exposure risk assessment, and indoor air quality management. The approach also offers a transferable methodology for rapid mass-transfer prediction in other organic compound–porous material systems.

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Seyedrezaei, M., Becerik-Gerber, B., Roll, S. C., Lucas, G., Narayanan, S.

How environmental conditions shape workload in hybrid work: a longitudinal mediation analysis.

Building and Environment, Vol. **303**, (2026)

Hybrid work alters workload experiences, yet the environmental attributes linking workspace location to subjective outcomes remain poorly understood. We conducted a four-month field study of 19 hybrid office workers, collecting 1,238 daily self-rated NASA-TLX workload dimensions alongside continuous indoor environmental quality (IEQ) monitoring across home and office workspaces. IEQ sensors measured temperature, humidity, CO_2, total volatile organic compounds (TVOCs), $PM_{2.5}$, and noise. In this exploratory study, mixed-effects models indicated that office workspaces were associated with higher mental demand, physical demand, time demand, effort, and frustration, but also with higher self-rated performance. Compared to home workspaces, offices exhibited more stable and generally lower concentrations of key indoor air-quality indicators, particularly CO_2, TVOCs, and $PM_{2.5}$. Multilevel within-person mediation analyses explored whether IEQ features showed indirect associations with workspace-workload relationships. TVOCs primarily operated through suppressor-like patterns: elevated concentrations at home were associated with increased mental demand, time demand, effort, and frustration, partially offsetting the lower workload levels otherwise associated with working from home. CO_2 variability showed dual roles, acting as a suppressor for mental demand while showing a pattern in which it was associated with a substantial portion of the observed home-office difference in physical demand. Low-humidity exposure showed indirect associations with time and physical demand, while $PM_{2.5}$ exposure was associated with a meaningful portion of the performance gap between locations. These findings are exploratory and should be interpreted with caution; nonetheless, they suggest that home air quality, particularly ventilation and pollutant control, may be a relevant factor in hybrid workers' workload experience, alongside substantial individual variability in environmental sensitivity.

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Un.Escap.

Indoor air quality management guidelines.

UN.ESCAP 2026. 110 p.

Indoor air quality (IAQ) is an important public health and environmental management issue, as people spend a large proportion of their time in indoor environments, such as homes, schools and workplaces. While outdoor air quality management can contribute to improved indoor conditions, indoor environments also contain specific pollution sources that may affect health, comfort and well-being. This RAPAP study introduces a Three-Tier Framework based IAQ guidelines to support ESCAP member States in strengthening IAQ management according to their national circumstances, institutional readiness, monitoring capacity and available resources. The framework provides a practical and flexible entry point for progressive action. The guideline presents key aspects of indoor air pollution, including common sources, health effects and management considerations. It also provides recommended IAQ values, monitoring approaches and maintenance practices for priority indoor environments, together with illustrative applications in different country contexts. The guideline is intended to support awareness-raising, policy development and practical pathways for improving IAQ across the Asia-Pacific region.

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Momen, A., Ghaeni, G., Rostami, R.

Influence of painting and background materials on BTEX levels in indoor environments.

Indoor and Built Environment, (2026)

This study investigates the indoor air pollution generated by painting activities, particularly the emissions of volatile organic compounds such as benzene, toluene, ethylbenzene and xylene (BTEX). To evaluate the impact of ventilation, background materials (chipboard, wood, plaster) and paint types (plastic, acrylic, oily) on BTEX concentrations, air sampling and gas chromatography-mass spectrometry analysis were conducted. The results demonstrated substantial reductions in ethylbenzene (41.07?µg/m3/day) and o-xylene (73.60?µg/m3/day) on ventilation days. However, the highest benzene and toluene concentrations were 550.98 and 364.64?µg/m3, respectively. Background materials significantly influenced BTEX levels, while paint type only affected ethylbenzene, o-xylene and combined xylenes. Notably, the cancer risk (CR) was highest among individuals aged 52?60 years, with all CR values exceeding 10?4, indicating elevated risk according to EPA guidelines. In contrast, the hazard quotient values were below 1, meeting USEPA and WHO safety thresholds. These findings emphasize the importance of ventilation and material selection in minimizing BTEX exposure, with implications for public health, indoor air quality (IAQ) management and control policies.

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Moura, P. C., Alieksieiev, V., Domingues, H., Pessanha, S., Vassilenko, V.

An Innovative Multi-Parameter Environmental Sensor System for Real-Time Indoor Air Quality Monitoring in Industrial Facilities.

Sustainability, Vol. **18** n°(14), (2026)

Ensuring adequate indoor air quality (IAQ) in industrial environments is essential for protecting worker health, particularly in facilities characterized by chemical emissions and complex layouts, such as automotive painting lines. This study presents the implementation and field evaluation of a low-cost multisensory electronic system prototype designed for continuous, long-term monitoring of six key environmental parameters: temperature, relative humidity, atmospheric pressure, carbon dioxide equivalent (CO_2 eq), total volatile organic compounds (VOC), and an overall Indoor Air Quality (IAQ) index. The system consists of autonomous sensing stations with integrated multi-parameter MEMS sensors and a centralized data aggregation hub. The system was engineered to ensure metrological stability across power cycles, adaptive energy management, and robust long-range wireless communication, thereby addressing common limitations of conventional industrial monitoring solutions. The prototype was deployed in an operational automotive manufacturing plant, where seven sensing stations were installed along the painting line for a two-week continuous monitoring campaign, identifying process-dependent peaks in CO_2 and VOC concentrations and corresponding reductions in IAQ values. The system was able to identify CO_2 peaks as high as 2997.7 ppm (Sensor 3) in localized industrial zones, significantly exceeding standard indoor thresholds. At the same time the system demonstrated the ability to detect VOC fluctuations with a resolution capable of capturing peaks up to 144.1 ppb (Sensor 3) during high-activity shifts. All sensors provided continuous and reliable data over an extended monitoring period. The measured trends and value ranges were consistent with expected industrial conditions, indicating satisfactory system performance under real operating conditions. Overall, the results demonstrate that the developed multisensory prototype is a promising, portable, and economically sustainable solution for distributed continuous IAQ assessment in complex industrial environments, with strong potential for scalable large-scale implementation in occupational health protection and environmental sustainability frameworks.

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Tanaka, T., Sigehuzi, T., Yamauchi, M., Oji, S., Watanabe, M., Tada, S., *et al.*

IoT-based indoor environmental monitoring and CO_2 prediction using FIWARE and Sigfox for smart laboratory environments.

Electrotechnica & Electronica (EE), Vol. **61** n°(1/2), (2026), 28 p.

This paper presents an Internet of Things–based system for continuous monitoring of carbon dioxide (CO_2), temperature, relative humidity, atmospheric pressure, and illuminance in a laboratory, together with a 15-min-ahead warning function for elevated CO_2 conditions. Sigfox-enabled sensors transmit measurements to ThingSpeak, while FIWARE Orion, QuantumLeap, CrateDB, and Grafana provide context management, time-series storage, and visualization. MATLAB retrieves the measurements, generates lagged CO_2 and recent-change features, and applies regression and ensemble classification models. Because high-CO_2 observations were infrequent, cost-sensitive learning and decision-threshold adjustment were employed. On the evaluated dataset, the threshold classifier achieved an accuracy of 62.63%, a precision of 0.09, a recall of 0.33, and an area under the receiver operating characteristic curve of 0.61. These results demonstrate the feasibility of the proposed end-to end monitoring architecture, although the model exhibited only modest predictive discrimination. Consequently, larger and more diverse datasets are required before the model can be considered for automatic ventilation control.

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Chen, Y.-H., Tuaño, K. B. S., Choi, A. E. S., Yang, Y.-H., Wan, M. W.

Life cycle assessment of HEPA filters in air purifiers for PM2.5 removal.

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

Indoor air quality is a critical public health concern, with fine particulate matter (PM2.5) exposure linked to severe respiratory and cardiovascular risks. Conventional air purification relies heavily on high-efficiency particulate air (HEPA) filters. The environmental trade-off between filtration health benefits and associated carbon burdens remains underexplored. This study applies a cradle-to-grave life cycle assessment (LCA) to evaluate the environmental profile of filter systems by integrating static material analysis with a dynamic simulation of operational scheduling strategies. Based on an empirical active lifespan, the assessment calculates a total non-use-phase filter carbon footprint of 3.82 kgCO_2-eq. per filter unit (covering raw materials, manufacturing, transportation, and end-of-life disposal). The raw material phase represents the primary environmental hotspot, contributing 78.49% of this embodied filter burden. Polypropylene (PP) material drives 75.28% of the cumulative cradle-to-grave emissions. A sensitivity analysis indicates that an 8% reduction in the primary polymer emission factor yields a 6.09% decrease in the total product carbon footprint. Discrete multi-stage fan-speed scheduling sequences eliminated operational energy overshoot with a 6% improvement in the carbon footprint when the pre-defined operational sequence interval was reduced from 5 min to 1 min. This study bridges the gap between filter material sustainability and use-phase operational efficiency. The dual strategy of material characterization and fan-speed scheduling optimization is proposed to establish an objective framework for sustainable air filter operation.

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Mohd, A., Leelawati, P., Sonam, R., Satyam, K.

Machine Learning in Gas and Air Quality Sensors: A Comprehensive Review.

Adroid Conference Series: Engineering and Technology, Vol. n°(DASGRI 2026), (2026), 372-390 p.

Air pollution is now considered one of the greatest public health threats. Detecting pollution is unfortunately often too slow, too costly or not precise enough, but millions of people suffer every year due to bad air quality. This paper reviews the application of machine learning (ML) techniques in the enhancement of gas sensors and air quality monitoring systems. We describe which types of sensors are most frequently employed, what the key challenges they are facing are, and how these challenges are addressed with different ML methods. We also review real-world case studies, present comparisons of different ML approaches and discuss the future of this field. The paper is simple enough for anyone to understand the interplay between machine learning and sensors — and how that interaction makes a bigger difference when it comes to breathing in cleaner air.

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Russo, R., Bottacin, A., Arcamone, G., Durbiano, F., Musacchio, C., Pavarelli, S., *et al.*

Metrological Characterization of Sensors for Thermal and Air Quality Parameters: A Case Study on a Multi-Sensor System for Monitoring Indoor Environmental Quality.

Chemosensors, Vol. **14** n°(9), (2026)

This paper presents the metrological characterization of low-cost sensors integrated into a multi-sensor system for Indoor Environmental Quality monitoring, developed within the MIRABLE project. The analysis focuses on two domains: the thermal domain, using Sensirion SHT45 and SEN55 temperature sensors; and the Indoor Air Quality (IAQ) domain, using an Infineon photoacoustic spectroscopy (PAS)-based sensor for carbon dioxide (CO2). All tests were conducted under controlled laboratory conditions using calibrated reference instruments. In the thermal domain, the influence of sensor integration within the device case was investigated at temperature (T) between 15 °C and 35 °C and relative humidities (RH) between 30 %rh and 60 %rh. The results revealed self-heating effects in the desk unit, causing temperature biases of up to 0.6 °C. In the IAQ domain, the repeatability and the impact of T and RH on CO2 measurements were evaluated. T was identified as the main influencing factor; whereas, RH had a negligible effect. These results were supported by statistical analysis ANOVA. A correction strategy based on concentration intervals is proposed for operation between 15 °C and 25 °C, with an expanded uncertainty (k = 2) of (3.26–6.42) ppm for the with-case configuration. These results support the reliable use of the MIRABLE system.

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Lee, J., Cho, D.-S., Lee, Y., Lim, S.-H.

Microchannel-integrated Cu3(HHTP)2 MOF chemiresistive sensor for rapid and sensitive room-temperature formaldehyde detection for air quality monitoring.

Sensors and Actuators B: Chemical, Vol. **468**, (2026) Formaldehyde is a major indoor air pollutant associated with acute irritation and long-term carcinogenic risks. Its ubiquitous emission from building materials, furniture, and industrial products underscores the need to monitor it at low concentrations. Although chemiresistive gas sensors offer advantages of simplicity, miniaturization, and cost, most room-temperature (RT) formaldehyde sensors exhibit slow response dynamics and insufficient sensitivity near regulatory exposure limits, primarily owing to kinetic and mass-transport limitations. Here, we report a microchannel-integrated chemiresistive formaldehyde sensor based on a conductive two-dimensional Cu3(HHTP)2 metal–organic framework (MOF). The sensor has interdigitated electrodes coated with Cu3(HHTP)2 and embedded within a trapezoidal microchannel, providing the benefits of enhanced mass transport and improved analyte adsorption kinetics. Computational simulations reveal that the microchannel structure increases local flow velocity and provides geometric advantages that facilitate mass transport and promote analyte–surface interactions at the MOF sensing surface. Hence, the sensor achieves a fast response time of 5.91 s at 250 parts per billion (ppb) formaldehyde, with a determined limit of detection of 4.93 ppb and a determined limit of quantification of 16.4 ppb, approaching the National Institute for Occupational Safety and Health recommended exposure limit. These results demonstrate that microchannel engineering combined with conductive MOFs is an effective strategy for overcoming kinetic and mass-transport limitations in RT chemiresistive sensors toward practical indoor air-quality monitoring.

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Abdullah, M.

[Mould Susceptibility of Bio-Based Insulation Materials: An Experimental Classification Using the Finnish Mould Sensitivity Framework.]()

This study experimentally evaluated 19 bio-based and 2 commercially available insulation materials under controlled hygrothermal conditions of 20°C and 97% relative humidity, with pine sapwood tested concurrently as the biological reference material, following the VTT protocol. Mould index progression was recorded visually over the full observation period, and the mould growth intensity factor k_1 was calculated for each material to assign Finnish sensitivity class designations. The results showed that mould susceptibility varied considerably across material groups: straw and reed were the most susceptible, reaching visible mould growth more than four times faster than the reference, while EPS, mineral wool, and wood chip board showed no growth at any stage. The clay matrix in ultra-light earth materials modified growth rates but did not eliminate mould risk, and hydrophobic bio-foam reached a higher final mould index than its hydrophilic counterpart despite its water-repellent surface properties. These findings confirm that bio-based materials cannot be treated as a uniform material group; susceptibility is governed by organic content, surface structure, and hygroscopic behavior rather than by material individual properties. The study concludes that straw, reed, and straw-clay composites require particular attention in hygrothermal design, while commercially processed materials such as WCB and mineral wool present substantially lower biological risk. Designers and specifiers working with bio-based insulation should rely on concurrent, controlled susceptibility testing rather than material category assumptions when assessing mould risk in moisture-exposed applications.

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Hou, F., Cheng, J. C. P., Huang, C., Li, A., Kwok, H. H. L., Wu, Z.

Multi-objective optimization for multi-zone HVAC system via physics-integrated predictive control framework with CFD-assisted visualization.

Building and Environment, Vol. **304**, (2026)

HVAC systems need to collaboratively optimize energy consumption, air quality, and thermal comfort under dynamic occupancy to address building energy efficiency and indoor environmental quality. However, traditional control strategies often struggle to balance these objectives, especially in enclosed spaces with high occupancy density and sudden variations, such as classrooms, where CO_2 can rapidly exceed safety limits within a short period without effective ventilation. Therefore, this study proposes a physics-integrated hierarchical predictive control framework using reduced-order models calibrated with measured data and a personalized “center-edge-corner” zoning strategy for adaptive spatial load matching. A three-layer decision mechanism (emergency response, optimal control, energy-saving control) enables dynamic multi-zone regulation. Results show that the proposed framework achieves satisfactory thermal comfort, with average temperatures of 23.0 °C in the uniform scenario, 22.6 °C in the center-concentrated scenario, and 22.4 °C in the dynamic scenario. In terms of air quality, the proportion of CO_2 concentration exceeding 800 ppm is 0% in the uniform scenario. In the center-concentrated scenario, the proportion exceeding 1000 ppm is 1.4%, with a 13.2% energy reduction compared to the baseline strategy. In the dynamic scenario, the energy consumption of the proposed strategy is nearly identical to that of the fixed strategy, but the proportion of CO_2 concentration exceeding 800 ppm is reduced from 10.2% to 5.9%. CFD simulation results provide high-resolution quantitative visualizations and further confirm that the proposed framework effectively prevents local pollutant accumulation and overheating in high-density zones. This study provides an efficient and deployable solution for intelligent energy-saving retrofits of existing buildings.

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Nair, A. N., Tanwar, H., Anand, P.

Occupancy Modelling Using Machine Learning for Building System Control.

Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions (5th Edition)

Buildings frequently depend on static occupancy profiles derived from building types and standard working hours, resulting in unwarranted energy consumption. Precisely predicting occupancy information is crucial for effective building system control and optimising indoor environmental quality. Conventional approaches for gathering occupancy data, including occupancy cameras, thermal imagers, Passive Infrared Sensors (PIR), and Radio-Frequency Identification (RFID) techniques, exhibit multiple constraints such as high costs, the need for specialised expertise during implementation, accuracy challenges, and concerns related to privacy issues. To address these limitations, the proposed solution in this study involves utilising machine learning and data-driven approaches to predict occupancy states using indoor air quality (IAQ) data, which includes parameters such as temperature, humidity, and indoor CO2 concentration. These data were collected using cloud-based IAQ sensors for 60 days. Ground truth occupancy information was collected for analysis using an occupancy camera. Using machine learning algorithms’ predictive capabilities and IAQ data, occupancy was inferred without additional sensors or equipment. Machine learning algorithms, such as k-Nearest Neighbour’s Algorithm (k-NN), Support Vector Machines (SVMs), Decision Tree (DT), XGBoost Classifier, and Random Forest classifier (RF), were evaluated based on their accuracy, precision, recall, F1-score, AUROC values, and computational time. The study utilised packages such as XGBoost library and Scikit-Learn to implement the models. Among the tested algorithms, the Random Forest algorithm demonstrated the highest performance in predicting occupancy states, followed by the XGBoost Classifier and DT. The Random Forest algorithm performed best, achieving 86% accuracy on the test dataset for occupancy state prediction. By employing data-driven methods and machine learning algorithms, the proposed solution offers a more cost-effective and non-intrusive approach to occupancy detection, allowing for improved control and optimisation of various building systems.

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Alkhatib, H.

Occupant Comfort: A Review of Assessment Methods, Models and Research Frontiers.

Journal of Engineering Research, (2026)

Occupant comfort is a perceived psychological, physiological and behavioural state that governs building liveability and a substantial share of operational energy demand. Research remains fragmented across four indoor environmental quality (IEQ) domains, thermal, air quality, visual and acoustic comfort, with occupant behaviour inconsistently represented in mainstream building simulation. This paper presents a critical narrative review, spanning peer-reviewed literature and the primary international standards governing each domain. This review covers: (i) the PMV-PPD framework and its documented limitations; (ii) adaptive thermal comfort models and their climatic scope; (iii) indoor air quality, ventilation adequacy and emerging pollutant chemistry; (iv) visual comfort and discomfort glare; (v) acoustic comfort across office, residential, healthcare and educational settings; and (vi) the shift from deterministic to stochastic and personalised, machine-learning-based occupant behaviour modelling. The PMV model correctly predicts thermal sensation in only 34% of field observations, and IEQ domains interact in ways that single-domain standards do not capture; in the cited CBE office survey evidence, acoustic-related items, particularly sound privacy, were among the most severe sources of dissatisfaction. Six literature gaps are identified, spanning multi-domain integration, climate generalisability, behavioural model standardisation, personalised comfort assessment, vulnerable populations and climate-resilient design.

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Budnarowska, K., Marć, M.

Occupational exposure to PAHs, PCBs, and VOCs representatives in port-industrial settings: A dual-track approach using silicone wristbands and diffusive passive samplers.

Marine Pollution Bulletin, Vol. **232**, (2026)

In this study, the personal exposure to SVOCs (PAHs and PCBs) was evaluated using wearable silicone wristbands. The indoor VOC concentrations in port-industrial settings were characterized using Radiello® diffusive samplers. VOC analysis revealed a terpene-dominated indoor profile, with Alpha-Pinene (11.0 ± 2.0 μg·m−3) and d-Limonene (6.60 ± 0.92 μg·m−3) indicating strong indoor emission sources. Benzene levels (from 4.09 to 5.82 μg·m−3) remained well below EU occupational thresholds, ensuring regulatory compliance. Silicone wristbands effectively captured a spectrum of SVOCs, with PCB 52 (ranging from 1.4 to 13 ng·g−1) and medium-molecular-weight PAHs (Fluorene, Phenanthrene) being most prevalent. The detection of Indeno[1,2,3-cd]pyrene and Dibenz[a,h]anthracene confirmed the infiltration of combustion-related pollutants from the adjacent port operations. All measured levels were below EU and US regulatory reference values. These findings validate wearable silicone wristbands as a non-invasive tool for personal multi-residue monitoring in a port-industrial indoor environment. This integrated passive sampling strategy provides a comprehensive fingerprint of occupational exposure, allowing for clear differentiation between indoor-generated VOCs and industrially-derived pollutants, which is essential for effective workplace safety management.

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Saporito, A. F., Hashmi, M., Yu, W., Michanowicz, D. R., Lebel, E. D., Lucha, N., *et al.*

Occupational Exposures in the Culinary Underbelly: Air Pollution in Restaurants.

Environmental Science & Technology, Vol. **60** n°(26), (2026), 18723-18732 p.

Occupational exposure to commercial cooking emissions has not been comprehensively studied, particularly in a Western context. This investigation measured the concentration and composition of volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM), carbon monoxide (CO), and black carbon (BC) in 18 New York City restaurants. Eight-hour gravimetric PM1,2.5,10 mass concentrations were measured in kitchen and dining areas, and PM1 was speciated using X-ray fluorescence. Evacuated canisters and XAD-2 sorbent tubes collected VOCs and PAHs, respectively, and were speciated using gas chromatography/mass spectrometry (GC/MS). Lastly, spatial concentration gradients for PM2.5 and day-of-the-week effects were considered in eight additional restaurants. A median PM2.5 concentration of 79.6 μg/m3 was found in kitchens, with real-time values spiking into the thousands of micrograms per cubic meter in some restaurants─values below the Occupational Safety and Health Administration 8 h permissible exposure limit of 5 mg/m3 for particles not otherwise regulated (respirable fraction), but well above the 24 h World Health Organization recommended ambient exposure limit of 15 μg/m3 for 2021. Benzene, a known carcinogen, was frequently detected in the kitchen areas, while PAHs were often undetected. These data warrant further investigation into the cardiopulmonary health of restaurant workers.

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Wang, W., Wang, Y., Lu, Z., Liu, Y., Li, T.

On-chip integrated NDIR CO2 gas sensor.

Microsystems & Nanoengineering, Vol. **12** n°(1), (2026)

This work reports an on-chip integrated non-dispersive infrared CO2 sensor, in which a microelectromechanical system infrared emitter and a thermopile detector are monolithically integrated on a silicon substrate. Portable CO2 monitoring, including wearable respiratory monitoring and portable environmental sensing, imposes stringent requirements on sensor miniaturization and rapid response. Conventional non-dispersive infrared sensors, constrained by discrete optical chambers and board-level packaging, face inherent trade-offs among compact size, fast response, detection range, and stability. To address these challenges, the optical chamber and device layout are co-optimized based on radiative transfer and thermal coupling principles to enhance infrared utilization while suppressing thermal crosstalk. Simulations show that the compact chamber achieves an effective optical path length of 11 mm with an optical coupling efficiency of 91.8%. An orthogonal optical–gas path configuration is further adopted to shorten the gas diffusion distance. The packaged sensor module remains highly compact, with dimensions smaller than 21 mm × 10 mm × 5 mm. Under a driving voltage of 2.5 V and a modulation frequency of 5 Hz, the sensor exhibits a response time of ~3 s, power consumption of 31 mW at a duty cycle of 10%, and a detection limit of 146 ppm, while maintaining stable performance over a wide temperature and humidity range. The on-chip integrated approach enables significant footprint reduction without compromising sensing performance, providing a promising pathway for portable CO2 monitoring.

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

Predictive early warning of heat and ventilation risks in naturally ventilated hospital wards using multi-output transformer-based models.

19th International Conference of the International Society of Indoor Air Quality & Climate (Indoor Air 2026), 14th - 18th June 2026, Republic of Singapore.

Hospital wards in tropical climates face persistent challenges in maintaining thermal comfortand indoor air quality, where mechanical ventilation is limited. Using over two years of 15-minute sensor data across 14 naturally-ventilated wards in two Ghanaian hospitals, togetherwith weather data, we develop an early warning system to forecast indoor temperature, relativehumidity, and CO_2 over a 24-hour horizon. We compared a multi-output XGBoost baseline witha Temporal Fusion Transformer (TFT). Results reveal a dual risk profile, where overheatingand high humidity are widespread and strongly diurnally structured, whereas CO_2 exceedanceis more localised and time-dependent. TFT improves temperature and humidity forecasting,while CO_2 prediction remains challenging and better served by XGBoost. Overall, the proposedapproach can inform proactive interventions ahead of critical events and demonstrates thefeasibility of data-driven ventilation forecasting in tropical hospitals, offering a scalablepathway toward smart, health-oriented indoor climate management in naturally ventilatedfacilities.

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Hewitt, N. J., Goebel, C., Diller, J., Fuchs, A., Fautz, R., Blömeke, B., *et al.*

Quantification of the exposure of consumers and hairdressers to formaldehyde and oxalic acid after application of hair straightening products containing glyoxylic acid.

Toxicology and Applied Pharmacology, Vol. **515**, (2026)

Glyoxylic acid (GA), the active ingredient of heat-activated hair straightening products (GHSPs) has been discussed in the context of acute kidney injury (AKI) via oxalic acid (OA) crystal formation and of heat-decomposition resulting in release of formaldehyde. Assessment of dermal absorption following realistic GHSP treatments with two marketed products resulted in maximally 7.73 µg/cm2 of bioavailable

GA/application. Considering the scalp area of 580 cm2, the systemic GA exposure of consumers was 4.48 mg, equivalent to 1.1 mg OA taking into account that 25% GA is dermally metabolized to OA. Assessment of GA exposure to stylists' hands indicated systemic OA levels in the range of 0.026 mg/day (assuming 3 treatments in one day). Compared to typical dietary and endogenous sources of OA of 22–45 mg/day, GHSP-dependent OA exposures of consumers and stylists were 20–41-fold and > 860-fold lower, respectively. PBK prediction of GHSP-dependent renal OA excretion of consumers was <1.27 mg/day compared with normal excretion of ∼25 mg/day and the 40 mg/day threshold associated with AKI. Predicted kidney OA concentrations during GHSP exposure further indicated that OA crystal formation is unlikely to occur. Assessment of the release of the GA heat-decomposition byproduct formaldehyde in the ambient air during GHSP treatment was <25 µg/m3 and below regulatory exposure limits e.g., 100 µg/m3 (WHO indoor air quality limit). In conclusion, quantification of GA-dependent formaldehyde and OA exposure indicates no health concerns for consumers and stylists under the described realistic GHSP treatment conditions.

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Lin, Z., Cao, J., Shi, S.

Rapid risk prioritization of indoor exposure to semi-volatile organic compounds using a novel steady-state inter-phase partitioning model.

Energy and Built Environment, (2026)

Semi-volatile organic compounds (SVOCs) are ubiquitous indoor pollutants whose partitioning among gas-, particle-, and dust- phases strongly influences their persistence and transport in indoor environments. Quantifying the multi-phase distribution of SVOCs is therefore critical for understanding associated exposure and health risks. In this study, we developed a steady-state inter-phase partitioning model that incorporates the kinetic coupling between airborne particles and settled dust and accounts for key indoor environmental influences, while retaining computational efficiency and improving the mechanistic representation of indoor SVOC partitioning. Evaluation against field measurements showed improved predictive performance over existing steady-state approaches, particularly for gas-dust partitioning. The model further enables integrated prediction of SVOC concentrations across multiple indoor phases from limited phase-specific measurements, providing a practical basis for exposure estimation and risk assessment. By coupling the model with multi-pathway exposure assessment and ToxCast bioactivity data, we further established a screening-level framework for the bioactivity-based risk prioritization of indoor SVOCs and associated exposure pathways. Application of the framework to residential indoor SVOC datasets compiled from seven field studies across different countries and regions showed substantial heterogeneity in assay-specific risk fingerprints, with different compounds and exposure pathways driving the same bioactivity endpoint across different indoor environments. Overall, this framework provides a practical tool for predicting indoor SVOC partitioning and for screening-level risk prioritization of chemicals and exposure pathways, while supporting air quality management in built environments.

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Liu, J., Xie, R., Fan, Z., Wu, J., Yuan, H., Tan, Y.

Rapid transient characterization of local formaldehyde and TVOC release from indoor surfaces using a detector-based dynamic concentration model.

Measurement Science and Technology, Vol. **37** n°(33), (2026)

Formaldehyde and total volatile organic compounds (TVOCs) are major indoor air pollutants that can negatively impact both indoor air quality and human health. Their primary sources are emissions from the surfaces of building and decorative materials. Conventional environmental chamber methods are generally complex and time-consuming, which limits their applicability for rapid on-site measurements. In this study, a cover-based transient measurement method was developed using a small stainless-steel cover, portable formaldehyde and TVOC detectors, and a dynamic concentration model. Three existing indoor surfaces, including a meeting-room cabinet, a meeting-room floor, and a study-room desktop, were monitored for 20 min under field conditions. Based on Fick's law and a transient mass balance incorporating the combined effects of leakage and sink adsorption, the measured concentration responses were fitted to derive a local area-specific release parameter E0 and an effective influence coefficient ke. The model reasonably reproduced the measured concentration curves, with R2 values exceeding 0.88 for all datasets. Repeated measurements generally showed consistent normalized transient response patterns and two-dimensional SSE analysis identified a principal numerical optimum for the fitted parameters while revealing appreciable correlation between the E0 and ke. These results indicate that the proposed method provides a practical basis for rapid comparative screening of short-term local release behavior from indoor surfaces under field conditions.

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Marossi, C., Lezcano, M., Brondino, M.

Restorative interventions in workplace environments: a systematic review of theories, methods, and environmental exposures.

Journal of Environmental Psychology, Vol. **114**, (2026)

Work environments play a crucial role in shaping employees' health and well-being, as workers spend most of their time indoors. In recent years, increasing attention has been devoted to restorative workplace environments, particularly those integrating natural elements and biophilic design; however, existing evidence remains fragmented across theoretical frameworks, methodological approaches, and measurement strategies. This systematic review maps how restorativeness is conceptualized and investigated in workplace settings, focusing on theoretical grounding, types of restorative exposures, study designs, outcome measures, and methodological gaps. Following PRISMA guidelines, a systematic literature search was conducted in PsycINFO, PubMed, Scopus, Web of Science using a PICOS-based strategy. Thirty-three empirical studies conducted in occupational contexts were included. Data were extracted on study characteristics, theoretical frameworks, intervention types, outcomes, and methodological quality. Results show a strong reliance on Attention Restoration Theory and Stress Recovery Theory, with most studies examining short-term affective, cognitive, and performance-related outcomes. Real indoor nature and outdoor exposures were the most frequently investigated interventions. Despite a generally moderate-to-high methodological quality, validated measures of perceived restorativeness were rarely employed, suggesting that restorative qualities are often assumed rather than empirically verified. Moreover, most samples consisted of white-collar workers, highlighting the need for research in more diverse work environments, such as industrial settings. Overall, the findings underscore the need for greater theoretical coherence and consistent use of validated measurement tools. Framing the physical work environment as an active organizational resource within the Environmental Demands–Resources framework may support more rigorous research and evidence-based workplace design and organizational practices.

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Osman, M. R., Azid, A., Samsudin, M. S., Yunus, K., Abd Rani, N. L.

A review of indoor air quality in heritage buildings and confined spaces: Implications for occupational safety and health.

Vietnam Journal of Science and Technology, Vol. **64** n°(3), (2026), 395-411 p.

This review analyzes the sources, distribution, and health effects of IAQ degradation in historical and enclosed environments and evaluates existing regulatory frameworks, including ICOP 2010, in addressing these concerns. It compares IAQ standards with regulatory exposure limits set by organizations such as ICOP 2010, the Occupational Safety and Health Administration (OSHA), and the World Health Organization (WHO). The health effects of prolonged exposure to PM-bound heavy metals, asbestos fibres, and microbial contaminants are discussed, with particular emphasis on respiratory diseases, lung cancer, and neurological impairments. The paper also evaluates IAQ management strategies, including real-time air quality monitoring, ventilation improvements, filtration technologies, and personal protective equipment

(PPE). It highlights the effectiveness of mitigation methods in reducing occupational exposure and proposes future research directions to develop sustainable IAQ solutions in heritage conservation and underground infrastructure projects. Aligning IAQ control measures with ICOP 2010 guidelines ensures that workplaces adhere to best practices for safeguarding worker health, preserving historical structures, and maintaining regulatory compliance.

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Li, F., Fan, L., Wu, H., Cui, H.

Ru- and Nb-doped Janus PtSSe monolayer for hazardous gas sensing of HCHO, C6H6 and Rn: a first-principles investigation.

Surface Science, Vol. **775**, (2027)

Indoor air quality in archival environments is critically threatened by hazardous gases such as HCHO, C6H6, and Rn, which originate from collection materials and building structures remain largely undetected. Using first-principles theory, this study investigates the structural stability, electronic properties, and gas adsorption performance of noble metal (Ru and Nb)-doped Janus PtSSe monolayers as potential resistive sensing materials for three target gases. The results reveal that both Ru and Nb dopants preferentially substitute at the Se site, and Nb-doping enhances the electron-donating capability of the substrate, leading to stronger adsorption energies and greater charge transfer compared to Ru-doping. Band structure analysis shows that Nb-PtSSe exhibits larger bandgap modulations with somewhat higher sensing response. Specifically, HCHO and C6H6 are chemisorbed behaving chemiresistive detection, while Rn, as noble gas with low chemical reactivity, behave weak physisorption and polarization-induced charge redistribution that achieves a tiny response. Recovery time analysis reveals that Nb-PtSSe suffers from long desorption times, while Ru-PtSSe achieves significantly faster recovery at 398 K. Thus, Ru-PtSSe emerges as a practically viable candidate for fast-recovery applications. This work not only provides a theoretical foundation for developing PtSSe-based gas sensors but also highlights the critical role of dopant selection in tailoring sensing performance for cultural heritage preservation applications.

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Putra, K. T., Rahaman, M., Lai, Y. A., Syamsi, M. I., Isnansyah, M. Y., Aditama, B., *et al.*

A Scalable IoT Architecture for Continuous Indoor Air Quality Monitoring in Smart Buildings with Asynchronous Event-Driven Communication.

2026 23rd International Joint Conference on Computer Science and Software Engineering (JCSSE)

Smart building monitoring plays a crucial role in ensuring energy efficiency, occupant comfort, and operational safety, particularly in environments where continuous connectivity cannot always be guaranteed. However, conventional Internet of Things (IoT)-based monitoring systems remain overly complex, heavily dependent on cloud-centric architectures, and limited in scalability. To address these challenges, this study proposes a scalable IoT architecture for continuous Indoor Air Quality (IAQ) monitoring in smart buildings, leveraging asynchronous event-driven communication between edge sensing units and a cloud backend. The proposed system integrates a resource-efficient edge device equipped with multi-modal IAQ sensors (temperature, humidity, CO2, and particulate matter) to enable real-time data acquisition, adaptive configuration, and energy-efficient operation. Unlike fully cloud-dependent approaches, the architecture supports distributed processing, where preliminary data handling is performed at the edge, while the backend enables real-time data ingestion, Machine Learning (ML)-based analytics, and bidirectional control. The system is evaluated across representative indoor environments, including reception areas, parking zones, and kitchen spaces, demonstrating stable real-time performance and reliable data transmission. Quantitative results indicate CO2 concentrations ranging from 566.09 ppm to 1207.5 ppm, temperatures between 29.9 °C and 32.74 °C, relative humidity from 47.7% to 62%, and PM2.5 levels of 12.6–16.28 µg/m3, while extreme conditions show PM10 exceeding 18,000 µg/m3. Overall, the proposed architecture provides an efficient and scalable solution for continuous IAQ monitoring in smart buildings.

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Tsuchiya, S., Yanagi, U., Kim, H., Shimonosono, K., Kagi, N.

Seasonal Variations and Indoor–Outdoor Characteristics of Fluorescent Aerosol Particles in Japanese Office Buildings.

Biosensors, Vol. **16** n°(7), (2026)

Fluorescent aerosol particles (FAPs) are widely used as a real-time proxy for primary biological aerosol particles; however, their seasonal characteristics and size-resolved distributions in office environments remain poorly understood. In this study, FAPs were measured in ten office spaces located in four distinct regions of Japan during summer and winter using a real-time Bioaerosol Sensor. Indoor and outdoor FAP concentrations, indoor/outdoor ratios, and the size-resolved FAP fraction were evaluated. Indoor FAP concentrations were generally below 100 particles per liter (p/L), although peak concentrations of 140 p/L in summer and 195 p/L in winter were observed. Significant seasonal differences were detected in most offices, with several buildings showing higher concentrations in winter. Many offices exhibited relative humidity levels below 40% during winter, suggesting that dry indoor conditions may have promoted particle resuspension and contributed to elevated FAP concentrations. Indoor–outdoor comparisons suggested contributions from both indoor sources and outdoor infiltration. The size-resolved FAP fraction increased markedly with particle size, with median indoor values reaching 40–74% for 2.0–5.0 μm particles and 96–100% for particles > 5.0 μm. These findings indicate that FAPs in office environments are strongly associated with coarse particles and exhibit substantial seasonal and building-dependent variability.

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Patil, S., Sudha, A., Nagasarvari, G., Swaminathan, P.

Silver nanowire-sensitized titanium dioxide for flexible, room temperature dual-gas sensing.

Ceramics International, (2026)

The development of flexible gas sensors capable of room-temperature operation is critical for next-generation wearable environmental monitoring platforms. Here, we report a flexible dual-gas sensor based on silver nanowire-titanium dioxide (Ag NW)-TiO2 nanocomposite fabricated on a polyethylene terephthalate (PET) substrate via direct writing and drop-casting. The nanocomposite was optimized at a 1:4 Ag:TiO2 volume ratio, yielding the most favorable sensing performance toward both NO2 and CO2 at 25 °C without external heating. The enhanced performance is attributed to a Schottky-type interface at the Ag–TiO2 interface and Ag NW-assisted chemical sensitization with spillover-mediated processes which collectively lower the activation barrier for gas adsorption and expand the electron depletion layer. The optimized sensor exhibited response/recovery times of 47/26 s for 5 ppm NO2 and 52/31 s for 300 ppm CO2, with sensitivity of 1.2 and 0.8%, respectively. Mechanical flexibility was confirmed by consistent sensing performance under both flat and bent configurations, as well as repeated bending cycle measurements. Notably, this is the first report wherein relative humidity was found to act as a dual-role modulator of sensing behavior, suppressing NO2 response via competitive adsorption of hydroxyl groups while simultaneously enhancing CO2 response through hydroxyl-assisted carbonate formation, with a crossover transition observed between 50%–60% RH. These findings establish Ag NW–TiO2 nanocomposites as promising candidates for low-power, room-temperature detection of toxic and greenhouse gases in flexible sensing platforms. This work uniquely demonstrates a flexible PET-based Ag–TiO2 sensor operating at room temperature with humidity-driven dual selectivity, which has not been reported previously.

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Noh, S.-K.

A Study on AIoT-Based Indoor Air Quality Management for Comfortable Indoor Air Quality and Electrical Power Consumption Reduction.

Electronics, Vol. **15** n°(16), (2026)

Recently, the Internet of Things (IoT) has evolved into the Artificial Intelligence of Things (AIoT) through its combination with artificial intelligence (AI) technology and has become capable of providing intelligent services in all industrial sectors. Globally, energy consumption within buildings is continuously increasing alongside the advancement of IT and AI technologies. Since this increase is attributed to various causes—ranging from large-scale climate change to small-scale indoor environmental factors (air quality) and health factors—research aimed at reducing indoor energy consumption is actively underway. In particular, in the home environment where people spend a significant portion of their day, maintaining indoor air quality (IAQ) is critical for health, and energy conservation in heating, ventilation, and air conditioning (HVAC) systems is essential. In Korea, the number of single-person households is increasing and was expected to reach 36.1% of all households by 2024, leading people to live in increasingly smaller homes. This study aimed to verify residents using contactless facial recognition to prevent pandemics such as COVID-19 and to provide comfortable indoor air quality. Resident facial recognition was performed by identifying residents' faces in images captured by the Pi camera using OpenCV's Haar feature-based cascade classifier. Indoor air quality measurements were conducted in four indoor locations, measuring various environmental factors (PM2.5, CO2, etc.) based on environmental sensors and the IoT. Furthermore, to manage indoor air quality, AI was utilized based on the measurement data to classify the four spaces, with a success rate of 96%. Additionally, considering the indoor area of the experimental environment (97 m2), it was confirmed that operating a 70 W air purifier only when the resident is indoors can reduce power consumption by approximately 33–75% compared to running it 24 h a day.

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Kaushal, A., Rameshkrishnan, L., Bakhirathan, A., Kiran Kumar, L. G.

Thermal Comfort and Indoor Air Quality Assessment of a Single-bed Intensive Care Unit Using Impinging Jet Ventilation.

Journal of Applied Fluid Mechanics, Vol. **19** n°(10), (2026), 2824-2836 p.

Thermal comfort and indoor air quality in intensive care units (ICUs) are strongly influenced by ventilation strategy and airflow organization. This study presents a combined experimental and numerical investigation of a simplified single-bed ICU room ventilated using an impinging jet ventilation (IJV) system. The effects of air change rate (16 ACH and 18 ACH) and outlet configuration (single and split outlet) on airflow distribution, thermal stratification, indoor air quality, and thermal comfort were systematically evaluated. Experimental measurements were conducted under controlled conditions and used to validate three-dimensional steady-state CFD simulations. The numerical results showed good agreement with experiments, with deviations in air velocity limited to 0.05–0.1 m/s and temperature variations within measurement uncertainty. The IJV system maintained low air velocities (< 0.3 m/s) and acceptable temperature ranges (24–27 °C) within the occupied zone. Indoor air quality assessment indicated mean CO_2 concentrations below recommended limits, while the split-outlet configuration enhanced contaminant removal by promoting upward transport and reducing recirculation zones. Thermal comfort analysis showed Predicted Mean Vote values within −0.5 to +0.5 and Predicted Percentage of Dissatisfied below 10%. The split-outlet configuration at 16 ACH provided the most balanced performance. Although energy consumption was not explicitly quantified, reduced airflow suggests potential for improved energy performance. The findings provide experimentally validated insights for optimizing ICU ventilation strategies.

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Verriele, M., Nathalie, R., Thévenet, F., Crunaire, S., Locoge, N.

Translating Exposure into Action: A Cross-Disciplinary Framework for Healthier Indoor Environments.

Indoor Air 2026. Singapore, Singapore

Making indoor air quality information actionable remains a major challenge, as exposure datararely translate directly into changes in practices. Sensory cues and normative representationsstrongly shape misperception of indoor air quality in domestic and professional environments.Based on participatory field studies conducted in domestic, community, and occupational contexts, this work examines how individuals perceive, interpret, and act upon exposure information. Results show that inclusion in monitoring processes legitimizes exposure as a shared concern and can foster recognition, particularly in occupational settings. Although participants readily identify feasible and low-cost action levers, these intentions do not systematically lead to measurable exposure reduction. Technical limitations of low-cost sensors, combined with data delivery modalities, complicate interpretation and source attribution. Overall, the findings highlight persistent gaps between data, perception, and action, and call for integrated technical and social approaches to support effective indoor air quality improvement.

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Basil, A.-a. M., Okwuosa, C. C., Anih, E. K., Basil, B., Ibem, E. O.

Window typology as a determinant of indoor air quality in naturally ventilated tropical African offices.

Scientific Reports, Vol. **16** n°(1), (2026)

Indoor air quality (IAQ) is a critical determinant of health and productivity in tropical African office environments where natural ventilation is the primary ventilation strategy, yet the influence of architectural factors such as window typology remains understudied. This study examined how casement, projecting, and louvered window systems, along with associated architectural features, affect measured IAQ in naturally ventilated government offices in Enugu, Nigeria. Using a cross-sectional observational design, the study assessed 54 offices and measured carbon monoxide (CO), carbon dioxide (CO2), formaldehyde (HCHO), total volatile organic compounds (TVOC), particulate matter (PM2.5), temperature, and relative humidity (RH). Data were analyzed with ANOVA and multivariate linear regression to isolate the effects of window typology while controlling for structural covariates like headroom, floor area, occupancy, etc. Significant IAQ differences were observed across window types, and the multivariate models identified window typology as a robust predictor for HCHO, RH and PM2.5. Casement windows consistently produced the most favourable IAQ profile, yielding the lowest adjusted pollutant concentrations. Compared to casement windows, projecting windows were associated with higher RH ($B = 3.61\%$, $p = 0.003$), higher PM2.5 ($B = 3.17$ μg/m3, $p = 0.005$), and higher HCHO ($B = 0.012$ mg/m3, $p = 0.019$). Similarly, combined louvered + projecting windows were associated with significantly higher RH ($B = 1.64\%$, $p = 0.045$), PM2.5 ($B = 2.19$ μg/m3, $p = 0.005$), and HCHO ($B = 0.008$ mg/m3, $p = 0.021$) than casement types. Adjusted PM2.5 was lowest in casement offices (3.83 μg/m3), while projecting-window offices recorded the highest adjusted RH (70.56%). Although unadjusted findings suggested window-related differences in carbon dioxide, the final regression indicated that the number of windows ($B = -9.24$, $p = 0.041$), rather than typology, was the stronger predictor. Overall, the study demonstrates that window geometry is an important determinant of pollutant dilution and moisture control in naturally ventilated tropical office buildings, and that performance-based window selection represents a low-cost passive strategy capable of improving indoor environmental quality and supporting energy efficiency.

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Tan, H., Othman, M. H. D., Wong, S. J., Kek, H. Y., Wang, B., Lee, K. Q., *et al.*

Would Heat Sources and Human Thermal Plumes Affect Indoor Airflow and Particle Dynamics in Healthcare Facilities: A State-of-the-Art Review.

Energy, (2026)

Heat generated by human occupants and equipment in indoor healthcare environments significantly influences airflow patterns and airborne particle transport. Although healthcare facilities are designed to limit pathogen spread through controlled ventilation, heat emissions from medical devices, lighting, and human bodies can disrupt airflow, altering the dispersion and deposition of infectious aerosols. This review synthesizes experimental studies and computational fluid dynamics simulations to evaluate how thermal sources interact with indoor airflow and particle behaviour. The mechanisms of buoyant plume formation are examined in detail, with particular focus on human-generated plumes arising from metabolic heat, which typically ranges from 58 to 116 W/m2. These plumes can deflect exhaled air at velocities around 1 m/s, whereas higher exhalation speeds above 1.5 m/s resist such deflection. The influence of localized heat sources, such as surgical lamps emitting up to 255 W/m2 and medical devices around 110 W/m2, is also discussed. Different ventilation strategies, including displacement ventilation, vertical downward systems, and temperature-controlled personalized airflow delivery are evaluated. Notably, personalized airflow maintained at 21–24°C can expand the clean air zone around burn patients by up to 82%, reducing particle deposition. The interactions among supply air jets, human thermal plumes, and shear flows are further explored, particularly where plume velocities reach up to 0.275 m/s. Overall, this review emphasizes the critical role of thermal effects in indoor air quality management and highlights the need to integrate heat source considerations into the design and optimization of ventilation systems to mitigate airborne infection risks in healthcare settings.

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Gomes, I., Abreu, R., Ferdov, S., Simoes, R., Costa, C. M., Carneiro, J.*, et al.*

Zeolite- and Metal–Organic-Framework-Based Mixed-Matrix Membranes for Volatile Organic Compound Detection: Recent Advances and Challenges.

Advanced Sustainable Systems, Vol. **10** n°(8), (2026)

ABSTRACT Real-time and selective detection of volatile organic compounds (VOCs) remains a major challenge in environmental monitoring, indoor air quality assessment, and breath analysis, particularly in humid and chemically complex atmospheres. Conventional analytical techniques provide high accuracy but are often unsuitable for continuous and portable sensing, while standard sensor platforms frequently suffer from cross-sensitivity and limited selectivity. In this context, mixed-matrix membranes (MMMs) have emerged as promising functional layers for VOC detection by combining the processability of polymers with the molecular recognition properties of porous fillers. Among these fillers, zeolites offer well-defined pore architectures, size/shape selectivity, and improved hydrophobicity in high-silica compositions, whereas metal?organic frameworks (MOFs) provide exceptional structural tunability, high surface area, and chemically tailored adsorption sites. This Perspective summarizes recent advances in zeolite- and MOF-based MMMs for VOC sensing, with emphasis on membrane composition, filler?polymer compatibility, humidity effects, detection performance, and device integration strategies such as selective coatings, filters, and preconcentration layers.

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