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

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Yari, M. H., Esmizadeh, E., Riahinezhad, M., Defo, M., Wang, L., Dragomirescu, E.

Advancing liquid diffusivity characterization in porous building materials: A novel single-sided NMR approach.

Journal of Building Engineering, Vol. **121**, (2026)

Moisture ingress significantly affects the long-term durability and structural integrity of building materials, with consequential implications for hygrothermal behavior, energy efficiency, and indoor air quality. Understanding moisture transport within porous materials is crucial for accurately predicting these associated performance outcomes, wherein liquid diffusivity, a fundamental parameter, plays a vital role in modeling and simulating such transport phenomena. While various techniques exist for determining liquid diffusivity, accurate characterization of liquid diffusivity remains challenging due to methodological limitations like a lack of resolution and size limitations. The single-sided Nuclear Magnetic Resonance (SS-NMR) overcomes these limitations, enabling high-resolution, non-invasive profiling for accurate liquid diffusivity determination. The current work introduces a novel experimental protocol for determining the liquid diffusivity in porous materials using SS-NMR methodology. Leveraging the high resolution of NMR MOUSE (200 µm), this method captures detailed moisture profiles, which are subsequently used to determine liquid diffusivity as a function of water content through Boltzmann transformation. The optimal moisture profiles were modeled using linear regressions with two fitting parameters. Six types of materials were tested, comprising three wood species (fir, spruce, and pine) and three sheathing boards (two glass-mat sheathings and oriented strand board (OSB). Comparative analysis revealed significant differences between the liquid diffusivity values obtained by using the proposed SS-NMR-based methodology and the conventional Künzel empirical approach, which relies on the water absorption coefficient for liquid diffusivity estimation. These findings indicate that the choice of characterization method for liquid diffusivity can profoundly influence subsequent hygrothermal modeling outcomes and post-analysis macro-scale building performance assessments.

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Ling, Y., Huang, C., Tong, L., Ye, J., Yang, G., Dai, X.*, et al.*

Characteristics of VOC emissions from furniture manufacturing factories in Nankang, China.

Atmospheric Pollution Research, (2026)

Industrial emissions of volatile organic compounds (VOCs) have led to elevated concentrations of ground-level ozone and potentially adverse effects on human health. In recent years, the furniture manufacturing industry has gradually become an important source of VOC emissions. In this study, field sampling was carried out in five wooden furniture industrial areas in Nankang, a typical industrial district in central China. 64 VOC species were observed within six categories in 40 factories during summer and autumn. Aromatics are the main compounds in both organized and fugitive emissions, accounting for 34.7%–42.02% of total VOCs (TVOCs). The seasonal concentrations of TVOCs at four urban sites were followed as winter > autumn > summer > spring, and the maximum concentration of 634.26 µg/m3 was nearby the industrial areas. Exceedances of fugitive VOC emissions were observed at a single factory during summer, primarily associated with solvent usage. Five factors were obtained from the positive matrix factorization model: chlorinated solvent usage, solvent usage, adhesive cleaning solvent usage, traffic exhaust, and petrochemical industry emission. The chlorinated solvent usage source, characterized by halohydrocarbons, contributed consistently across seasons. Combined with the Hybrid Single-Particle Lagrangian Integrated Trajectory model, it was found that the southern industrial zone was the main local

source of VOCs in Nankang. Xylene, trimethylbenzene, toluene, and ethylbenzene provided most contributions to ozone formation potential and secondary organic aerosol potential both in industrial and urban areas, highlighting aromatics control as a direct method to mitigate secondary pollution. The health risk assessment showed that all industrial areas had high non-carcinogenic risks (HI > 1), while the northern industrial zone had a moderate carcinogenic risk due to cyclohexane (1.02E-4). These findings underscore the need for targeted and actionable VOC control in the furniture manufacturing industry, including strengthened fugitive-emission management, substitution of high-OFP aromatics and chlorinated solvents with water-based or low-VOC alternatives, and prioritized guidance for high-emitting zones and coating/solvent-use processes.

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Zhao, Y., Chen, Y., Shang, B., Wang, Y., Du, Y.

Chemical characterization and source apportionment of PM2.5 inside and outside subway platforms of Tianjin during winter.

Air Quality, Atmosphere & Health, Vol. **19** n°(3), (2026), 39 p.

During winter, PM2.5 Samples were meticulously collected from two metro station platforms and their adjacent outside areas in Tianjin. The mass concentrations, along with the compositions of metal and metalloid elements, polycyclic aromatic hydrocarbons (PAHs) and water-soluble ions within PM2.5 were precisely determined. Employing the positive matrix factorization (PMF) receptor model, a detailed source apportionment of PM2.5 was carried out at the two subway platform sites and their corresponding outdoor locations. The results revealed that the PM2.5 concentration on the platforms was significantly higher than that in the outdoor areas. Most metal and metalloid elements exhibited higher concentrations on the platforms compared to the outside. Notably, in the metro station equipped with half - height platform gates, the concentrations of Al, Cr, Mn, Ni, Sb, Pb, Co, Naphthalene (NAP), Acenaphthene (ANA), Phenanthrene (PHE), Fluoranthene (FLT), and Pyrene (PYR) were considerably higher than those in the station with platform screen doors. In contrast, no significant differences were observed in the concentrations of water-soluble ions between the platforms and the outdoor areas. PMF analysis indicated that subway train operation and coal combustion were the dominant sources of PM2.5 at the Honghuli Metro station (HHL) site. At the Jinghe Road Metro station (JHR) site, biomass burning, fossil fuel combustion, and brake pad wear were identified as crucial sources. For both the outside of Honghuli Metro Station (OHHL) and the outside of Jinghe Road Metro station (OJHR) sites, secondary aerosol emerged as the primary pollutant source. Significantly, the external environment of the metro stations exerted a substantial influence on the pollutant types present on the subway platforms. This study provides valuable insights into the air quality in subway environments, which is of great significance for urban environmental management and public health protection.

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Plasson-Simoni, L.

Conceptual definition of Ambient Intelligence (AmI) in the era of Smart Buildings. : User-centred applied contributions.

Université Pascal Paoli. Thèse 2025

Ce travail propose un changement de paradigme dans la conception des bâtiments intelligents, en intégrant l'AmI comme moteur de contextualisation, et l'ontologie comme levier d'interprétation des données. Il suggère de réorienter les pratiques vers des architectures sémantiques capables de répondre aux défis de l'IoT, tout en recentrant la logique de service sur l'usager. À terme, ces résultats ouvrent la voie à des recommandations pour la standardisation des Smart Buildings autour de modèles interprétables, adaptatifs et évolutifs.

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Rijal, S., Maharjan, K.

Environmental CO_2 Levels and Stroop Cognitive Performance Among Emergency Department Staff: An Observational Study.

Journal of Nepal Medical Association, Vol. **64** n°(294), (2026), 81-85 p.

he air we breathe at work may directly shape how we think and make decisions. Research suggests that even moderately high levels of carbon dioxide (CO_2) indoors,common in crowded spacescan slow cognitive performance. This is a criticalconcern for Emergency Departments, where staff operate under intense pressure, often in spaces with poor ventilation, while also battling the cognitive toll of shift work. Methods: To explore this in a real-world setting, we observed 85 doctors and nurses in the Emergency Department of Patan Hospital over five months. We continuously monitored CO_2 levels in their workspace. At the end of their shifts, staff completed a brief,computerized cognitive test (the Stroop Color-Word Test) to measure attention and mental flexibility. We then compared test performance between shifts with lower (<1000 ppm) and higher (≥1000 ppm) CO_2 levels. Results: A total of 85 Emergency Departments staffs were enrolled in the study out of which 50 (58.82%) doctors and 35 (41.17%) nurses. The mean age of participants was 32.4±6.8 years and 53 (62.12 %) were female. Out of 3 shifts that were observed 35 (41.17%) was day shift and 25 (29.41%) was night shift and remaining 25 (29.41%) staffs were taken at evening shift. Conclusions: Real-world Emergency Department staff exposed to moderate CO_2 elevations did not demonstrate clear impairment on Stroop interference metrics. Circadian disruption and fatigue appear to be stronger drivers of cognitive slowing than CO_2 within typicalranges.

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Schurk, Y. D.

Evaluating HVAC Air Filter Performance.

ASHRAE Journal, Vol. **68** n°(2), (2026)

The article explains the critical distinction between a filter's laboratory-tested efficiency and its real-world effectiveness in reducing indoor air contaminants. Topics include fundamental air filtration mechanisms, the limitations of standardized testing methods; and practical system design considerations that impact performance.

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Zang, T., Awada, M., Becerik-Gerber, B.

Exposure Window Size Exploration: Linking Indoor Air Quality to Fatigue in Office Environments.

In: Computing in Civil Engineering 2025. 2026. 1049-1057 p.

Carbon dioxide (CO2), total volatile organic compound (TVOC), and particulate matter 2.5 (PM2.5) are common indoor air quality (IAQ) factors associated with fatigue symptoms in offices, which affect workers? well-being and productivity. A longitudinal understanding of these IAQs? effects on fatigue remains limited. This study assesses the viability of predicting fatigue symptom in office based on exposures to CO2, TVOC, and PM2.5 over varying timeframes. Indoor air data were collected from one male office worker in his office over 4 months, alongside Ecological Momentary Assessments (EMAs) to evaluate if he experienced fatigue or tiredness in the past hour. Supervised machine learning models XGBoost were trained to classify if the participant would experience fatigue symptoms based on the office air data, with SHAP analysis further identifying significant IAQ factors contributing to these symptoms. The study offers preliminary insights into how indoor air pollutant exposures drive office worker experiences of fatigue from ML perspective.

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Yang, J., Wu, Y., Ng, S. T.

From compliance to perception: A systematic review and quantitative synthesis of indoor environmental quality in healthcare facilities.

Results in Engineering, Vol. **29**, (2026)

Healthcare buildings often meet regulatory thresholds for indoor environmental quality yet fall short of delivering satisfactory user experience. This review followed PRISMA guidance and quantitative analysis method to synthesize evidence on the alignment between objective compliance and subjective cognition in dynamic healthcare settings, focusing on visual, acoustic, indoor air quality, and thermal domains with physical environment as a complementary lens. Across studies, compliance and perception exhibit only a moderate coupling, with pronounced domain-specific and contextual variability. Acoustic domain emerges as a persistent weak link—improvements rarely translate proportionally into better perceived soundscapes—while air quality shows frequent decoupling from perceptions shaped by odor, freshness, and episodic events that conventional metrics overlook. Visual and thermal conditions display weak-to-moderate translation of compliance into perceived quality. The care context and user role (patient, clinical staff, visitor) systematically modulate these relationships, with controlled or mixed scenarios enabling more reliable translation from compliance to experience. Evidence further indicates a nonlinear, threshold-like pattern: moving environments from low to moderate compliance yields the largest perceptual gains, whereas benefits taper at higher levels. We propose a dual-channel evaluation framework—a saturating compliance–response curve paired with standardized perception—to diagnose “high-compliance/low-perception” and “low-compliance/low-perception” quadrants and set prioritized, domain–context–role–specific interventions. The findings argue for complementing compliance-based governance with perception-oriented design and operations to achieve user-centered healthcare environments.

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Tejani, A., Toshniwal, V.

Human-Centric HVAC Systems: Linking Thermal Comfort, Cognitive Performance, and Energy Efficiency.

International Journal of Emerging Trends in Computer Science and Information Technology, Vol. **7** n°(1), (2026), 48-56 p.

Human-centric Heating, Ventilation, and Air Conditioning (HVAC) systems symbolize a new paradigm of changing the energy-focused functionality of the building climate control to the performance-oriented and occupant-conscious design. Traditional HVAC systems are based on fixed set point and simplistic comfort factors, and tend to ignore the dynamic relationship between the indoor environmental condition, human thermal comfort, cognitive performance and energy use. The paper introduces a combination of human-centred HVAC system, which identically connects the models of thermal comfort, cognitive performance, and energy optimization in the smart building conditions. The presented framework will utilize real-time environmental monitoring, occupancy and behavioral data collection and subjective feedback on comfort to build a holistic image of the indoor environment and occupancies. Predicted Mean Vote (PMV) and adaptive comfort models are used to determine the relationship between thermal comfort and contextual and behavioral data, using cognitive performance indicators. Models using machine learning are utilized to represent non-linear relationships between the comfort and the performance, as well as to predictive evaluate the response of occupants. These models guide all forms of intelligent control and optimization procedures that dynamically determine and modify HVAC operation in order to yield harmony in comfort, cognitive performance and energy consumption. Through experimental assessment and comparative analysis, it has been shown that occupant-focused control systems can be very effective in enhancing thermal comfort and cognitive performance and lead to substantial savings in energy consumption relative to traditional fixed-setpoint HVAC systems. These findings justify the use of human-centered HVAC systems as an effective strategy to improve occupant health, performance, and sustainability that can be implemented as the main element of the next-generation intelligent and energy-efficient buildings.

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Fu, J. S., Davis, W. T.

Indoor Air Quality.

In. CRC Press; 2026. 317-351 p.

The sixth edition of a bestseller, Air Quality provides students with a comprehensive overview of air quality, the science that continues to provide a better understanding of atmospheric chemistry and its effects on public health and the environment, and the regulatory and technological management practices employed in achieving air quality goals. Maintaining the practical approach that has made previous editions popular, the chapters have been reorganized, new material has been added, less relevant material has been deleted, and new images have been added, particularly those from Earth satellites. New in the Sixth Edition New graphics, images, and an appended list of unit conversions New problems and questions Presents all-new information on the state of air quality monitoring Provides the latest updates on air quality legislation in the United States Updates the effects of air pollution and CO2 on climate change Examines the effects of the latest changes in energy production and the related emissions and pollutants Offers broadened coverage of air pollutant emissions and air quality in a global context This new edition elucidates the challenges we face in our efforts to protect and enhance the quality of the nation's air. It also highlights the growing global awareness of air quality issues, climate change, and public health concerns in the developing world. The breadth of coverage, review questions at the end of each chapter, extensive glossary, and list of readings place the tools for understanding into your students' hands

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Russo, R., Rolle, F., Durbiano, F., Pennecchi, F. R., Pavarelli, S., Festevole, C.*, et al.*

Indoor Air Quality monitoring using low-cost sensors: Experimental set-up and characterization procedure.

13th International Gas Analysis Symposium (GAS 2026)

Monitoring indoor environmental quality is a key requirement for addressing challenges related to smart cities and human health, including indoor air quality. Traditionally, indoor air monitoring has relied on high-end instrumentation, limiting large-scale and widespread deployment. The increasing availability of low-cost sensors offers new opportunities for scalable monitoring systems, provided their metrological performance is properly characterised. In this context, the Italian PRIN project MIRABLE (Measurement Infrastructure for Research on Healthy and Zero Energy Buildings in Novel Living Lab Ecosystems), involving the Italian National Metrology Institute (INRiM) and the Politecnico di Torino, aims to develop a multidomain measurement infrastructure for indoor environments using low-cost sensors in a full-scale living laboratory. At INRiM, a dedicated calibration system was developed to ensure the metrological traceability of CO2 and CO measurements obtained from low-cost sensors. Reference gas mixtures were prepared gravimetrically according to the International Standard ISO 6142-1 and dynamically diluted to reach low concentration levels. Calibration was carried out using a primary non-dispersive infrared (NDIR) reference analyser and a specially designed calibration chamber. This study presents calibration results for selected CO2 low-cost sensors and a preliminary evaluation of measurement uncertainty. The same methodology will be extended to low-cost CO and NOx sensors in future work.

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Li, C., Pan, S., Wang, C., Qin, M., Wang, X., Wang, Y.*, et al.*

An integrated assessment model for indoor environmental quality performance and passenger satisfaction in metro carriages.

Tunnelling and Underground Space Technology, Vol. **172**, (2026)

The indoor environmental quality (IEQ) of metro carriages significantly influences passengers' health and comfort. However, IEQ research and standards for transport microenvironments often lack a holistic approach because they emphasize isolated environmental aspects, which limits comprehensive IEQ assessment and prioritizing improvements. Furthermore, the specific requirements associated with short-term exposure in dynamic and enclosed transit environments are often overlooked. Therefore, to address these research gaps, this study, for the first time, proposes an IEQ model that uses multiple linear regression based on physical environment measurements collected from Changchun Metro Lines 1 & 2

carriages and questionnaire responses from 1059 passengers in December 2021. The results show that all measured environmental parameters comply with Chinese metro and transportation standards, yet environmental satisfaction rates remain below 60%. This divergence between objective compliance and subjective dissatisfaction indicates that current standards do not adequately meet the special requirements for short-term exposure in dynamic enclosed scenarios. Additionally, the average carriage temperature of 24.2 °C is significantly higher than the neutral temperature of 19.0 °C and slightly higher than passengers' most satisfactory temperature of 23.6 °C, which indicates a potential for energy savings. Finally, IEQ assessment model shows that, unlike aboveground buildings where thermal comfort serves as the core driver, metro carriage IEQ satisfaction is predominantly driven by indoor air quality (IAQ, β = 0.392) and acoustic comfort (AC, β = 0.379) followed by visual comfort (VC, β = 0.188). This model provides a reference for designers to select design strategies that better meet public expectations and to guide revisions of relevant standards.

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Singh, A. K., Joshi, N.

Integrating Passive Architecture and Smart HVAC Systems for Energy-Efficient Building Design: Towards Greener Urban Infrastructure.

Journal of Research in Civil and Architectural Engineering, Vol. **10** n°(1), (2026)

The building sector is one of the largest energy consumers globally, with significant environmental impacts due to heating, ventilation, and air conditioning (HVAC) operations. This paper presents an integrated approach to energy-efficient building design by combining passive architectural strategies with smart HVAC systems. Passive design techniques such as natural ventilation, solar orientation, thermal insulation, and daylighting significantly reduce energy demand. Meanwhile, Internet of Things (IoT)-based HVAC systems further optimize energy use through intelligent control, occupancy sensing, and climate-responsive adaptation. This synergy not only reduces operational energy consumption but also contributes to achieving green building certifications like LEED and BREEAM. Through detailed analysis, simulation-based case studies, and real-world applications, the paper evaluates the energy-saving potential, cost-effectiveness, and environmental benefits of this hybrid approach.

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Zhang, Y., Huang, Y., Ren, T., Yu, J., Yang, X.

Investigation of fresh air supply strategies and airflow rates for radiant air-conditioned rooms.

Energy and Buildings, Vol. **358**, (2026)

Radiant air-conditioning systems are typically operated in conjunction with outdoor air ventilation systems to simultaneously ensure indoor thermal comfort and air quality. However, the extent to which different outdoor air delivery strategies affect indoor air pollution characteristics—such as CO2 concentration, its spatial distribution, and air age—remains insufficiently clarified. This study compares the effects of three fresh air supply strategies—ceiling air supply, floor air supply, and impinging jet ventilation—on indoor air quality in residential rooms equipped with a radiant air-conditioning system and a mechanical ventilation unit. The results indicate that the vertical variation in CO2 concentration within the breathing zone remains within 30 ppm, with limited horizontal spatial variability. The average CO2 concentrations associated with ceiling and floor air supply are nearly identical, whereas impinging jet ventilation results in concentrations that are 0–19 ppm higher. The supply air temperature has a negligible effect on the mean air age in rooms served by a radiant air-conditioning system. Considering both CO2 concentration and air age, ceiling-based fresh air supply is recommended for radiant air-conditioned rooms. Furthermore, this study analyzes indoor CO2 distributions under varying fresh air CO2 concentrations and air supply rates for ceiling-supplied radiant cooling rooms. A method for determining fresh air volume based on the upper limit of breathing-zone CO2 concentration is proposed, suggesting that the fresh air volume in radiant air-conditioned rooms should be increased by a correction factor of 1.1 relative to values calculated using current standards.

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Nisa, E. C., Tsai, C.-W., Kuan, Y.-D., Lai, C.-C.

IoT-based real-time anomaly detection and power prediction model in ice-storage air-conditioning system.

Journal of Energy Storage, Vol. **154**, (2026)

The integration of internet of things (IoT) technologies into ice-storage air conditioning (IAC) systems is essential for enhancing system reliability. However, research on real-time anomaly detection and power prediction for brine chillers in IAC systems is limited. This study addresses this critical gap by presenting an IoT-based framework that combines a one-dimensional convolutional autoencoder (1D-CAE) for unsupervised anomaly detection and a multi-layer feedforward neural network for power prediction, specifically tailored to brine chillers in IAC systems. Deployed on a Jetson Orin Nano, the system collects minute-level operational data and updates deep learning models weekly to ensure continuous adaptability. The anomaly detection model achieved coefficient of determination (R2) exceeding 0.96, demonstrating high alignment between reconstructed and original data. Using synthetic anomaly data for testing, the study highlights the potential for fine-tuned detection thresholds to improve fault identification in real-world applications. The power prediction model achieved consistent accuracy, with mean absolute error (MAE) values of 2.873 and 2.864, and root mean squared error (RMSE) values of 4.197 and 4.226, for training and testing datasets, respectively, alongside a consistent R2 of 0.983. Additional validation using three charging-phase datasets further supports the model's reliability. By integrating these models into an IoT framework, this study enables operators to continuously monitor, detect anomalies early, and simulate operational scenarios, enabling proactive maintenance and optimized energy management for IAC systems.

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Ma, H., Wang, S., Gu, J., Xie, Q., Wang, W., Dong, S.*, et al.*

IoT-based smart environmental control and air emission management in animal farming: A systematic review.

Information Processing in Agriculture, (2026)

Emissions of hazardous gases from livestock production have had significant detrimental impacts on both global ecosystems and public health. In recent years, smart technologies have outperformed conventional biochemical and physical methods in improving indoor air quality and mitigating pollutant emissions, thereby promoting sustainable development in animal agriculture. This systematic review focuses on the application of Internet of Things (IoT) and Artificial Intelligence (AI) technologies within the Precision Livestock Farming (PLF) framework for regulating indoor air quality and reducing emissions in livestock housing systems. Research indicates that the integration of IoT and AI (AIoT) shows remarkable efficacy in monitoring indoor air quality and controlling pollutant emissions. However, current IoT-based pollution monitoring and control systems still face challenges, including sensor accuracy and reliability, the development of intelligent control strategies, cost management, and energy consumption optimization. To foster collaborative innovation and integrated applications of hardware, software systems, and data analysis technologies, these challenges must be addressed, future research must focus on developing low-cost, durable sensors, creating multi-variable control strategies that integrate animal behavior, and constructing end-edge-cloud collaborative AI and IoT integrated (AIoT) systems to improve air quality, reduce pollutant emissions in livestock housing, and drive the low-carbon transformation. To the best of the author’s knowledge, no systematic review for air pollution and emissions in livestock housing based on IoT and AI was found. Therefore, to fill this gap, this review aims to provide valuable references and data support on how IoT and AI models enable low-cost, smart control of pollutant air and emissions in animal farming.

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Chen, X., Li, J., Yang, H., Wu, Y., Wang, H., Zang, J.

Numerical simulation and experimental study: dynamic ventilation patterns and air quality analysis in moving subway trains.

Tunnelling and Underground Space Technology, Vol. **172**, (2026)

The subway environment has a significant impact on passengers' health and comfort. To assess the actual air quality inside moving subway trains, field tests were conducted on three subway lines in Shanghai to measure carbon dioxide concentrations and fresh air supply rates in different train cars. Further numerical simulations were used to study the dynamic ventilation rate based on changes in surface pressure as the train operates in tunnels. The results showed that CO2 concentrations gradually increased from the front to the rear of the train, with CO2 concentrations in the trailing cars being 1.17 to 1.24 times higher than those in the leading cars. The fresh air supply rates in the front and trailing cars of moving subway trains may deviate from the design values by + 20% and −25%, respectively. Therefore, the fresh air rate needs to be increased from the design value of 32% to approximately 50%. The primary cause of cross-drafts is the pressure difference during operation, and poor airtightness exacerbates this phenomenon. Therefore, an optimized balance between pressure regulation and vehicle body sealing is required. The research results can serve as a reference for subway ventilation design and in-car environmental control.

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Damle, V., Sharma, S. K., Soni, S. K.

Performance comparison of inclined solar chimney with and without a perforated plate for natural ventilation using computational fluid dynamics.

AIP Conference Proceedings, Vol. **3385** n°(1), (2026)

A solar chimney offers an effective passive cooling solution for building ventilation. The efficiency of solar chimneys can be enhanced by incorporating perforated plates into their design. This research compares the performance of solar chimneys with and without perforated plates, with a particular focus on the inclined solar chimneys. Numerical analyses were conducted using ANSYS CFX, enabling the generation of heat and pressure graphs to evaluate system performance. The use of CFD significantly reduces the time and cost associated with experimental methods while providing detailed insights into system behavior. The results demonstrate that the inclusion of perforated plates improves the efficiency of inclined solar chimneys, increasing airflow by 1.69% and reducing the computational domain temperature by an average of 0.58 °C. These enhancements result in improved thermal performance, highlighting the potential of perforated plates to optimize solar chimney designs for efficient energy systems. The study underscores the effectiveness of CFD in evaluating and improving passive cooling solutions for sustainable building ventilation.

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Ren, J., Fang, Z., Zhang, X., Zou, Q., Chen, Y.

Progress and challenges of the development of design weather parameters for building air-conditioning system: A literature review.

Renewable and Sustainable Energy Reviews, Vol. **231**, (2026)

In the context of the imperative for energy saving and carbon reduction, along with increasing attention to public health, developing advanced design weather parameters is crucial for designing air-conditioning (AC) systems that can reduce energy consumption and maintain acceptable indoor environment. Traditional design weather parameters that are excessively extreme lead to overestimated design cooling loads, resulting in oversized AC systems and wasting energy. This study conducts a comprehensive analysis concerning inherent limitations of traditional design weather parameters and identifies critical factors for determining rational design weather parameters. Due to improper adoptions of fictitious design weather parameters and outdoor non-guarantee rate in traditional methods, the designed AC systems exhibit poor energy performance and deviate from the design objective. Therefore, a novel framework is developed based on the joint mapping relationship between outdoor weather parameters and indoor

cooling loads, joint distribution characteristics of weather parameters, and feature importance analysis to improve the accuracy of design weather parameters. On this basis, general coincident design days (CDDs) corresponding to room categories are derived to adapt to engineering applications. Besides, a CDD prediction method based on a decision chain is proposed for big data applications. AC systems designed by CDDs are demonstrated to achieve energy conservation and maintain indoor thermal comfort. The future research is intended to promote more refined and flexible CDDs to cope with environmental pressures and extend their applications while improving energy efficiency.

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Zhaurova, M., Horttanainen, M., Child, M., Soukka, R.

Reducing indoor CO2 levels in office buildings via CCUS: An LCA perspective for energy and emission reduction.

Energy and Buildings, Vol. **357**, (2026)

Simultaneously reducing building energy consumption and maintaining acceptable indoor CO2 levels is challenging. This study applies a system-level life cycle assessment to compare two approaches for indoor CO2 level reduction: increasing the supply airflow rate and direct air capture (DAC) of CO2 from ventilation for utilization (CCUS) in methanol, carbonated concrete blocks (CCB), and stainless-steel slag construction blocks (SSSB). Greenhouse gas (GHG) emissions and energy demand were compared across energy scenarios to identify optimal emission reduction and energy performance strategies. Results show that buildings with integrated DAC have 51% lower energy consumption than those with the increased airflow rate. At the system level, increased airflow consistently demonstrates the highest energy demand and GHG emissions across all scenarios, whereas CCUS approaches reduce these emissions by 8–31%. The heat source is the key factor determining the most effective emission reduction strategy. For conventional heat supply, replacing steam curing with CO2 curing in CCB is the most effective approach, whereas SSSB is most effective with low-carbon heat. CCB also provides the greatest energy savings among the analyzed options. Scaling to Finland's office building stock reveals that the CO2 utilization potential of construction blocks is constrained by market capacity in CCB and feedstock availability in SSSB. Methanol production, while offering the highest utilization potential, provides only modest emission reduction (9%). Although building-integrated CCUS cannot significantly contribute to Finnish emission targets, it offers crucial co-benefits including energy savings, regulatory advantages, and substitution of emission-intensive products, making it a valuable supplement to industrial CCUS strategies.

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Abedi, S., Soleimani-Alyar, M., Nasiri, R., Jafari, A. J., Yarahmadi, R.

Research on dynamic operation of active botanical biofilters for indoor air purification: Multi-objective analysis and optimization.

Energy and Built Environment, (2026)

Active botanical biofilters (ABBs) are potential solutions for low-energy indoor air purification; nevertheless, their dynamic performance and life-cycle implications under operational settings are inadequately investigated. This study develops and experimentally validates a 4E (Efficiency, Energy, Economic, Environmental) framework, coupled with a digital-twin–enabled, time-resolved life-cycle assessment (DT-LCA), to evaluate a portable ABB treating formaldehyde under dynamic indoor loads. A three-species planting and a multi-component porous substrate were tested at four airflow set-points (62–94 $m^3\ h^{-1}$) and four inlet concentrations (0.05–1.00 mg m^{-3}) in 60-min dynamic trials. Key performance indicators included single-pass removal efficiency (SPRE), elimination capacity (EC), clean air delivery rate (CADR), pressure drop (ΔP), quality factor (QF), and energy efficiency ratio (EER), normalized to two functional units: FU-1 (1 m^3 of clean air) and FU-2 (one operational year at 8 h day^{-1}, 300 days yr^{-1}). Across all scenarios, SPRE ranged from 33.4 to 94.0 %, EC between 1.60 and 50.37 mg h^{-1}, with CADR between 31.4 and 64.6 $m^3\ h^{-1}$. QF spanned 0.36–2.38 mmH_2O^{-1}, while EER varied from 0.20 to 0.89 $m^3\ W^{-1}\ h^{-1}$, peaking at the lowest fan setting and declining monotonically with increasing power. DT-LCA results show that use-phase electricity

dominates life-cycle burdens and identify moderate-to-low airflow regimes as the operating region that maximizes QF and EER. These findings support the use of ABBs as energy-aware IAQ control elements via the integrated 4E/DT-LCA framework, providing actionable guidance for the design, control, and HVAC integration of next-generation ABB systems.

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Derik Dwi, H., Yudi, K., Budi, S.

Sistem kontrol kualitas udara dalam ruangan berbasis Arduino. (Système de contrôle de la qualité de l'air intérieur basé sur Arduino)

SKANIKA: Sistem Komputer dan Teknik Informatika, Vol. **9** n°(1), (2026), 92-103 p.

Indoor air quality issues are increasing due to high exposure to pollutants such as carbon monoxide (CO) and PM2.5 particulates, especially in buildings located near highways. Most air control devices are still operated manually or continuously without considering actual conditions, making them inefficient and unresponsive to changes in air quality. This study designed an Arduino-based air quality control system capable of real-time monitoring and automatic control using MQ-7, PMS5003, and PIR sensors. The method employed was a prototype approach that included hardware design, microcontroller programming, and system function testing using black-box testing. The testing scenarios included conditions where CO and PM2.5 levels exceeded thresholds, human presence detection, and a combination of all parameters in two test rooms. The test results showed that the system was able to respond well to all scenarios, with the exhaust fan activating according to the predetermined control logic. Based on the analysis of the test results, the system achieved a 100% success rate in all scenarios tested and was able to display real-time air quality information via LCD. This study proves that the Arduino-based control system can work effectively in automatically maintaining indoor air quality and is an easy-to-implement solution.

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Banerjee, S., Si, T., Sachdev, D., Kharkar, T.

Smart Indoor Air Quality Monitoring Device with Automated Threshold-Based Control.

2025 13th International Conference on Intelligent Embedded, MicroElectronics, Communication and Optical Networks (IEMECON)

Indoor air quality (IAQ) has direct impacts on human health, comfort, and productivity. In this paper, the design and development of a Smart Indoor Air Quality Monitoring Device utilizing an ESP32 microcontroller are discussed. The device incorporates several environmental sensors to measure temperature, humidity, particulate matter (P M2.5 and P M10), carbon monoxide (CO), methane (CH4), dust, smoke, and gas leakage. A small OLED screen shows live readings, and a touch-sensitive interface enables users to browse through sensor information. IoT functionality facilitates effortless transfer of data to far-off servers or user dashboards. One of the most significant novelties of this system is its relay smart switch, which triggers purifiers, exhaust fans, or fire alarms automatically whenever pollutant levels exceed set limits. This capability lowers energy usage and extends the life of purifiers, so the system is efficient and cost-effective. Experimental testing demonstrates stable sensing, timely relay control, and quantifiable energy savings, making the device an effective product for everyday IAQ monitoring and control.

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Mim, M. A., Sharif, M. M., Rahman, F., Nahar, S.

Smart IoT Infrastructure for Workplace Efficiency and Energy Savings.

World Journal of Advanced Engineering Technology and Sciences, Vol. **18** n°(1), (2026), 140-156 p.

The rapid digitization of modern workplaces has led to increased reliance on electrical equipment, automated systems, and digital infrastructure, resulting in higher energy consumption and operational complexity. Conventional workplace infrastructure systems often operate independently, without real time

coordination or intelligent control, which leads to energy wastage, inefficient resource utilization, and reduced employee comfort. To address these challenges, this paper proposes a Smart Internet of Things (IoT) based infrastructure aimed at improving workplace efficiency while achieving significant energy savings. The proposed system integrates distributed smart sensors, intelligent controllers, cloud-based data analytics, and automated control mechanisms to continuously monitor environmental conditions, occupancy behavior, and equipment usage in real time. By analyzing collected data, the system dynamically optimizes lighting, heating, ventilation, air conditioning, and power usage based on actual workplace demand. Experimental evaluation and scenario-based analysis indicate that the proposed IoT framework can reduce overall energy consumption by a substantial margin while maintaining optimal indoor comfort levels. Additionally, automation reduces manual intervention and operational overhead, contributing to improved productivity and system reliability. The modular and scalable design of the infrastructure allows it to be deployed across various workplace environments, including offices, industrial facilities, and institutional buildings. The findings of this study demonstrate that smart IoT-enabled infrastructure provides an effective, sustainable, and future-ready solution for intelligent workplace management and energy efficient operations.

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배상환, 유정연.

A study on pollutant emission characteristics according to the manufacturing methods of ventilation air filters.

Journal of Odor and Indoor Environment, Vol. **24** n°(4), (2025), 361-366 p.

This study investigates the emission characteristics of volatile organic compounds (VOCs) and aldehydes (HCHO) from ventilation air filters manufactured using two different bonding methods: chemical bonding and thermal bonding. Small-chamber tests were conducted in accordance with KS ISO 16000-9:2006 to quantitatively compare the hazardous substance emissions of five filter specimens with varying bonding mechanisms and exposure surface conditions. The results show that filters produced by thermal bonding exhibited non-detectable (N.D.) levels of toluene, TVOC, and formaldehyde, demonstrating that this manufacturing method inherently minimizes chemical emissions by avoiding the use of adhesives. In contrast, filters manufactured through chemical bonding released formaldehyde ranging from 0.002 to 0.006 mg/m2·h, which is attributed to residual binder components used during the manufacturing process. Although these levels meet the highest grade criteria (≤ 0.008 mg/m2·h) in the Korean eco-friendly building material certification for wallcoverings, meaningful emissions were still observed, and potential grade changes may occur depending on adhesive type, solid content, and coating amount. Furthermore, this study found that differences in the exposed surface (single-sided vs. double-sided) significantly influenced calculated emission rates. This result revealed the limitations of applying building-material-based chamber test methods to filter materials through which air directly flows. These findings highlight the necessity of developing dedicated testing standards for ventilation filters, including appropriate exposure definitions. Overall, this research confirms that ventilation filters should be incorporated into institutional management frameworks alongside conventional building finishing materials, given their direct influence on indoor air quality.

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G P, Senthilkumar

Toxicological and environmental health effects on workers handling paints and coatings.

International Journal of Zoology and Applied Biosciences, Vol. **10** n°(6S), (2025), 288-292 p.

Workers employed in paint and coating industries are frequently exposed to a complex mixture of hazardous chemicals, including volatile organic compounds (VOCs), heavy metals, solvents, pigments, and reactive additives. These substances are known to exert a wide range of toxicological effects, such as respiratory irritation, neurotoxicity, dermatological reactions, oxidative stress, reproductive abnormalities, and long-term organ damage. In addition to their adverse health implications, emissions from paint and

coating processes contribute significantly to environmental contamination, affecting indoor air quality and posing broader ecological risks. This review analyzes the toxicological pathways, occupational exposure routes, and environmental health consequences associated with the production, handling, and application of paints and coatings. It also highlights associated risk factors, emerging scientific evidence, and the importance of engineering controls, continuous monitoring, and adherence to safety protocols for mitigating workplace hazards. The findings emphasize the urgent need for improved occupational safety practices and sustainable alternatives to ensure the wellbeing of workers and the surrounding environment.

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Morawska, L.

Ultrafine Particles in Ambient and Indoor Air: How Our Knowledge Has Evolved from 1990 to 2025.

Environmental Science & Technology, (2026)

Despite major progress, many questions remain. We need better models of new particle formation to predict local and global trends based on our understanding of their precursors and meteorology. We need to understand how UFP concentrations and characteristics will evolve as societies shift to cleaner energy and combustion-related emissions decline. It is uncertain whether UFP concentrations will decrease significantly or whether secondary particles (particles formed in the air from gaseous precursors) will become more dominant in areas with abundant natural or anthropogenic emissions precursors. The growing influence of climate-driven wildfires adds further uncertainty, and these events are expected to increase and intensify UFP air pollution. Much remains to be understood, and the “textbook” on UFP is still being written.

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Yu, H., Zuo, Z., Wang, C., Li, G.

Unsteady mechanisms of pulsed thermally buoyant jets for enhancing ventilation performance of indoor air supply outlets.

Building and Environment, Vol. **294**, (2026)

Improving indoor ventilation performance through dynamic airflow modulation is increasingly important for achieving energy-efficient and thermally comfortable built environments. This study investigates the unsteady behavior, mixing mechanisms, and dilution characteristics of pulsed thermally buoyant jets discharged from multiport indoor air-supply outlets. Validated three-dimensional numerical simulations based on the RNG k–ε turbulence model were performed, with model credibility established through similarity-based water-tank experiments. The effects of pulse frequency and temperature difference on jet structure, vortex evolution, entrainment, and ventilation-related dilution behavior were systematically examined for both vertical and horizontal outlet configurations. The results show that increasing thermal buoyancy enhances entrainment and strengthens outer counter-rotating vortices, which leads to improved jet dilution. Higher pulse frequencies suppress central vortices and promote lateral spreading. For vertical jets, higher pulse frequencies improve jet continuity and stabilize entrainment, resulting in increased dilution. In contrast, for horizontal jets, the misalignment between jet momentum and buoyancy causes low-frequency pulsation to promote large-scale unsteady structures and stronger mixing, thereby enhancing far-field dilution. These findings clarify the coupled roles of pulsation and thermal buoyancy in governing jet transport and dilution behavior and provide guidance for optimizing air distribution strategies oriented toward dilution-based ventilation performance in energy-efficient indoor ventilation systems.

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Pei, J., Qu, M., Dong, X., Xu, X., Lv, M., Cui, J.*, et al.*

Volatile organic compound emissions from human body at different activity levels - key compounds and emission rates.

Building and Environment, Vol. **293**, (2026)

Humans are important sources of indoor VOCs, especially in densely populated indoor environments and enclosed spaces. Human VOC emissions are closely related to activity level and therefore metabolism intensity; however, previous studies were mostly conducted in a sedentary state. In this study, human VOC emissions without the use of personal-care products at four different metabolic intensity levels were measured in an environmentally controlled chamber (8 m3, air change rate at 0.005 h-1) with eight Chinese adults. Six major VOC categories (ketones, aldehydes, alkanes, BTEX, acids, and esters) and five key compounds (acetic acid, acetone, decanal, nonanal, and hexanal) were identified, which represent the human VOC emission profile. The major VOC categories and their rankings were the same for females and males, while females presented higher total VOC (ΣVOC) emission rates than males did (without considering body mass), especially under the higher metabolic levels established. The major VOC emission categories, the contributions of major species, and key compounds did not significantly change at different metabolic levels, but the mean ΣVOC emission rates increased with increasing metabolic rates, ranging from 8989 μg/h to 21,163 μg/h. Aldehyde and alkene emissions significantly increased with increasing MET level. The CO2 concentration may underestimate the air quality, especially under lower MET levels, which is primarily the case indoors. The key VOCs emitted by participants, especially odorous VOCs need to be considered as supplementary air quality indicators. Quantitative human VOC emission data can be used to better predict indoor air quality and guide ventilation design, especially for enclosed environments.

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Wang, N., Liu, X., Liu, L., Liu, C., Wang, H.

A weak disturbance decoupling control strategy for air-handling units of the HVAC system.

Journal of the Franklin Institute, Vol. **363** n°(6), (2026)

Indoor air quality is one of important objectives for green buildings. Air handling unit systems (AHUs) are widely used to improve indoor air quality. Deviations of the humidity source intensity and heat load from their nominal values are treated as uncertainties, while deviations of the outdoor humidity ratio and temperature from their nominal values are regarded as disturbances. To achieve better control performance for indoor temperature and humidity, a weak disturbance decoupling control method is proposed for AHUs to attenuate the impact of disturbances and an adaptive weak disturbance decoupling controller is constructed. Compared with PD and feedback linearization control methods, it can be concluded from simulation results that the proposed controller has better precision and tracking performance.

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