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Google Scholar, Lens, WoS

Kidanemariam, A., Cho, S.

Advanced Metal–Organic Framework-Based Sensor Systems for Gas and Environmental Monitoring: From Material Design to Embedded Applications.

Sensors, Vol. **25** n°(21), (2025)

Environmental pollution is a global issue presenting risks to ecosystems and human health through release of toxic gases, existence of volatile organic compounds (VOCs) in the environment, and heavy metal contamination of waters and soils. To effectively address this issue, reliable and real-time monitoring technology is imperative. Metal–organic frameworks (MOFs) are a disruptive set of materials with high surface area, tunable porosity, and abundant chemistry to design extremely sensitive and selective pollutant detection. This review article gives an account of recent advances towards sensor technology for MOFs with application specificity towards gas and environment monitoring. We critically examine optical, electrochemical, and resistive platforms and their interfacing with embedded electronics and edge artificial intelligence (edge-AI) to realize smart, compact, and energy-efficient monitoring tools. We also detail critical challenges such as scalability, reproducibility, long-term stability, and secure data management and underscore transforming MOF-based sensors from lab prototype to functional instruments to ensure safe coverage of human health and to bring about sustainable environmental management.

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Doli, S., Talloori Sai, K.

Air purification using electrostatic plate and coupled with dehumidifier.

International Journal of Data Science and IoT Management System, Vol. **4** n°(4), (2025), 391-394 p.

Air pollution and humidity are two major contributors to poor indoor air quality that adversely affect human health and comfort. This paper presents the design, fabrication, and performance evaluation of a hybrid air purification system that combines an electrostatic precipitator (ESP) with a dehumidifier to simultaneously remove particulate contaminants and regulate humidity. The proposed system employs a high-voltage electrostatic plate assembly to capture fine dust, smoke, and microorganisms through electrostatic attraction, while the integrated dehumidifier condenses and removes moisture from the incoming air stream. The experimental prototype was tested for particle removal efficiency, humidity control, and energy consumption. Results indicate that the hybrid system achieved 91% particulate removal for $PM_{2.5}$ and 45–60% relative humidity reduction in a 20 m^3 enclosed space within 30 minutes. The integration of dehumidification enhanced ESP efficiency by reducing dielectric breakdown of moist air and improving charge stability. The study concludes that the combined system offers a cost-effective and energy-efficient approach for improving indoor air quality in residential and industrial applications

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Claudia CAMPANALE, Leonardo BARLUCCHI, Augusta PICCARDI, Marcello DE ROSSI, Giordano MORELLI, Jacopo LA NASA, Francesca MODUGNO, Lorenzo PALUMBO

Airborne Microplastics In Workplaces: Preliminary Findings From A Multi-Site Investigation Of Plastic Handling And Processing Facilities

Journal of Biological Research - Bollettino della Società Italiana di Biologia Sperimentale, Vol. **98** n°(S2), (2025)

Airborne microplastics (AMPs) are emerging contaminants of increasing global concern due to their persistence, small size, and potential for inhalation, allowing them to reach the human respiratory system.

Although current evidence suggests possible risks to respiratory health, the actual extent of the hazard to the general population remains unclear. Given these characteristics and the associated health risks, particular attention must be paid to environments where AMP exposure levels may be elevated.1 Therefore, we selected different work environments involving the handling and mechanical processing of plastic materials to assess the relevance of occupational exposure to AMPs. The experimental design involved sampling in five different industrial facilities, each characterized by different plastic material workings ranging from mechanical-biological processing of mixed municipal waste to plastic waste sorting, secondary raw material production, and processing of single polymers. At each site, five representative sampling locations were selected to capture different exposure scenarios: (1) a primary processing area with intense mechanical operations; (2) a secondary area with less intensive activities; (3) an office area, physically separated from production, serving as an indoor background; (4) a personal sampling point, using wearable devices to estimate individual exposure during work shifts; and (5) an outdoor control. Two parallel ambient air samples were collected at each location using low-flow pumps (15 L/min) equipped with total dust sampling heads. Following sampling, a dual analytical approach, specifically developed for AMPs, was set up, combining Py-GC-MS and fluorescence microscopy to integrate quantitative data on both particle number concentration (particles/m^3) and polymer mass concentration (µg/m^3). Preliminary results, obtained from two of the five plastic facilities investigated, show higher concentrations of AMPs within the indoor environments compared to outdoor controls. Within indoor spaces, processing areas exhibit elevated levels compared to office spaces confirming the contribution of mechanical plastic transformation activities to AMPs dispersion. Personal sampling of workers engage in direct plastic processing activities reveales higher microplastic concentrations than environmental sampling, indicating that close proximity to cutting and milling significantly increases exposure. Finally, the polymers identified reflect the specific processing activities and the predominant materials handled at each site.1. Gasperi J., Wright S.L., Dris R., et al. Microplastics in air: Are we breathing it in? Curr. Opin. Env. Sci. Hl. 2018, 1, 1-5.

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Onyejizu, J., Karlicek, R. F.

Airflow-Graph Modeling for Multi-Zone IAQ Forecasting.

Proceedings of the 12th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation. Colorado School of Mines, Golden, CO, USA

Accurate prediction of indoor carbon dioxide (CO2) is essential for improving indoor air quality and optimizing energy use under occupancy driven demand. Most sequence models overlook spatial coupling between rooms. We pose multizone CO2 forecasting as a spatiotemporal learning problem and introduce two hybrid models that combine GCN and LSTM, with a learnable, schedule gated, infiltration aware adjacency that is either fixed (Static GCN) or varies with door schedules and zone specific infiltration (Dyn GCN). The models are trained using real world weather and ambient CO2 boundary conditions. Dyn GCN reduces 24 h error by 16.6 ppm RMSE and 10.4 ppm MAE relative to an independent LSTM, and by 6.2 ppm RMSE and 3.7 ppm MAE relative to Static GCN, with all gains statistically decisive ($p < 10-30$). It also shortens 800 ppm early warning lags to about 6 minutes, learns interpretable airflow patterns consistent with building physics, and generalizes across climates, supporting demand controlled ventilation.

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Speranza, A., Sinisi, R., Caggiano, R.

Analysing the interplay of indoor and outdoor PM: a compositional data analysis approach.

Air Quality, Atmosphere & Health, (2025)

Indoor and outdoor PM (particulate matter) air pollution is a major environmental problem due to its potential impact on human health. To understand the exchange relationship between indoor and outdoor PM composition, the compositional data analysis technique has been applied to data obtained from a previous study. In this study, PM levels measured both indoors and outdoors in two California dwelling units during Fall were analysed. The results revealed two distinct scenarios. In unit 933, indoor PM contained

approximately 22% fewer coarse particles than outdoor PM. This difference was attributed to both the lack of indoor PM sources and limited air exchange due to residents' habit of keeping windows and doors closed. This likely induced gravitational settling of the coarser indoor PM fractions, enriching the finer ones. In this unit, no evidence of a direct link between indoor and outdoor PM was found, suggesting that outdoor PM did not influence indoor PM. Conversely, in unit 921, indoor PM contained approximately 72% fewer fine particles than outdoor PM. This result was attributed to the absence of indoor PM sources and continuous air exchange, as occupants routinely left windows and doors open during the day. Statistical analysis indicated a relationship between indoor and outdoor PM, suggesting that outdoor PM influenced indoor PM. The proposed method sheds light on the possible mechanism that influences the coarse and fine size fraction of indoor and outdoor PM, providing a useful technique for studying their complex relationship.

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Mehta, A., Kathuria, T., Kumar, S.

Application of Nanotechnology in Air Remediation.

In: Nanotechnology in Environmental Remediation: Perspectives and Prospects.

Bentham Science Publishers; 2025

The world's persistent daily development continues to cause unceasing damage to the air. As reported by the World Health Organization, over six million people worldwide lost their lives due to residing and working in environments affected by air pollution in 2016. Despite the effectiveness of traditional techniques such as desulfurization, denitrification, and dust removal in reducing emissions from the sources of stationary combustion, they have not proven successful in reducing the frequency of atmospheric haze conditions. Current research globally urges the advancement of technologies to create nanomaterials (NMs) capable of efficiently and intelligently trapping CO2 , CO, and other harmful gases from the air. Diverse NMs play pivotal roles as nano adsorbents, nanocatalysts, nanofilters, and nanosensors, showcasing the versatility and effectiveness of nanotechnological applications in this field. This technology facilitates air pollution remediation by treating volatile organic compounds, greenhouse gases, and bioaerosols through adsorption, photocatalytic degradation, thermal decomposition, and air filtration processes. This chapter specifically delves into the practical use of a range of NMs for air pollution remediation applications.

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Liang, W., Yu, X., Yang, X.

The ASHRAE indoor air quality procedure (IAQP): Introduction of method and discussion on practical implementation.

Building and Environment, Vol. **288**, (2026)

Outdoor airflow rate is a critical factor influencing both indoor air quality (IAQ) and building energy consumption. The Indoor Air Quality Procedure (IAQP) specified in ASHRAE Standard 62.1 provides a performance-based alternative to the prescriptive Ventilation Rate Procedure (VRP) for determining the outdoor airflow rate. Despite its theoretical robustness and the potential to improve IAQ while saving energy, IAQP remains significantly less adopted in engineering practice than the VRP. To address this gap, this study first introduced the IAQP method by explaining its theoretical foundation and key implementation steps. It then discussed several major challenges and proposed some potential strategies to promote its real-world application. Possible strategies and future efforts could focus on the development of a tiered risk-based contaminant selection list, open-access emission databases, regionally adapted design limits, an integrated IAQ-energy simulation and a hybrid objective-subjective evaluation framework. Realizing the full potential of IAQP will require interdisciplinary collaboration, comprehensive and reliable data, and user-friendly simulation tools. These advancements are essential for establishing IAQP as a viable and energy-efficient strategy for sustainable building design and operation.

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Anuar, N. a. S. A., Ismail, I.

Association Of Indoor Air Quality (IAQ) Parameters with Sick Building Syndrome (SBS) Symptoms in Gallery and Museum in Shah Alam, Selangor.

Junior Science Communication, Vol. **50**, (2025), 17-17 p.

This study was conducted to evaluate the relationship between indoor air quality (IAQ) parameters with sick building syndrome (SBS) symptoms. The selected buildings are Shah Alam Gallery and Sultan Alam Shah Museum in Shah Alam, Selangor which had been operated for more than 30 years. This research underscores the significance of IAQ in ensuring a healthy and productive indoor environment, particularly in older buildings where structural aging and outdated HVAC systems can exacerbate IAQ issues. By understanding the relationship between IAQ and SBS, building owners can implement appropriate interventions to improve occupant health and productivity, ultimately contributing to a safer and more comfortable indoor space.

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Hoffmann, C., Hauri, C., Primas, A.

Audit of low-tec ventilation systems in office buildings.

Journal of Physics: Conference Series, Vol. **3140** n°(9), (2025)

This study examined ten office buildings with simplified ventilation systems. The methodology comprised a user survey, the calculation of embodied energy in terms of greenhouse gas (GHG) emissions and measurements in four of the buildings. The survey shows that in winter 35 % of the participants are satisfied with the ventilation system, 45 % are moderately satisfied (N = 553). In summer the satisfaction rate is slightly lower with 25 % satisfied and 33 % moderately satisfied (N = 458). The measurements however show that the indoor air quality regarding CO2 (IDA (CO2) in all four buildings is better in summer (all buildings are class I), than in winter (all buildings: class II). Regarding indoor environment quality and temperature (IEQ (RT)) in winter all buildings are classified cathegory II, in summer the buildings vary between class I and III, with most of them in class II. GHG calculations show that by reducing HVAC it is possible to save up to 70 % of the embodied GHG emissions used for HVAC. By reducing ventilation alone, over 50 % of the embodied GHG emissions for HVAC can be saved.

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Huang, Q., Langenbeck, A. D., Frisch, J., Van Treeck, C.

Carbonfly: An easy-to-use Python library and Grasshopper toolbox for CO2-based indoor airflow and air quality CFD simulation.

Available at SSRN 5773504

This paper introduces Carbonfly, an open-source Python library and Grasshopper toolbox. This tool enables users to execute CFD simulations for CO2based indoor airflow and air quality analysis within parametric design workflows using the OpenFOAM framework in the background. Validated preset boundary conditions are provided and can be applied to building models with mechanical, natural, or hybrid ventilation systems. We have provided comprehensive documentation, video tutorials, and examples to guide users through the installation and utilization process. Carbonfly addresses the gap in easy-to-use CO2 simulation tools that can be integrated into the early design stages of buildings within a parametric design workflow in Grasshopper within Rhino. This is particularly significant for architectural design, especially in the context of healthy buildings, especially those centered on indoor air quality.

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Giorio, C., Zherebker, A., Li, Y.

Chapter 4 - Indoor air quality and particulate matter.

In: New Perspectives in Indoor Air Quality. Elsevier; 2026. 27-46 p.

There is strong evidence that exposure to airborne particulate matter (PM) causes adverse health effects such as chronic inflammation, asthma, and allergy. Epidemiology studies mainly relied on outdoor PM10 and PM2.5 (particles with diameter smaller than 10 and 2.5 µm, respectively) measurements in fixed monitoring stations, but it is now well known that indoor PM drives personal exposure, as humans spend a large proportion of their time in indoor environments at work and at home. This chapter discusses the spatial distribution of indoor PM concentrations, their seasonal variation, and most influencing factors such as ventilation and indoor and outdoor sources. In the past 30 years, several studies have been published on indoor PM concentration data covering hundreds or even thousands of households. For this chapter, data have been collected from 158 studies worldwide which monitored at least 20 households. Data show that PM2.5 concentrations are the most widely studied with a wide heterogeneity of indoor concentrations found by different studies in different countries around the world. Indoor PM2.5 was rarely found to meet World Health Organization guidelines, and it was mainly impacted by indoor sources such as smoking, heating, cooking, cleaning, and personal care. Infiltration of outdoor PM is also an important contribution to indoor PM, with decreasing impacts moving away from trafficked roads and industrial sites. For the coarser PM fraction, outdoor dust events can also contribute to indoor PM10. Low-income countries and poor-quality housing are also determining factors negatively impacting indoor air quality which raises questions into environmental justice.

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Settimo, G., Capolongo, S., Gola, M., Ianiri, G., Avino, P.

Chapter 24 - Common contaminants that threaten hospital indoor air quality.

In: New Perspectives in Indoor Air Quality. Elsevier; 2026. 317-328 p.

Indoor air quality (IAQ) in hospital environments is a critical factor influencing the health and well-being of patients, healthcare workers, and visitors. This chapter explores the main chemical and biological contaminants that compromise IAQ in healthcare facilities, highlighting their sources, health risks, and regulatory considerations. Common pollutants include volatile organic compounds (VOCs), particulate matter (PM10, PM2.5), polycyclic aromatic hydrocarbons, heavy metals, and microbiological agents such as bacteria, fungi, and viruses. This chapter discusses the impact of hospital-specific factors, including ventilation systems, cleaning and disinfection procedures, and building materials, on IAQ. Additionally, monitoring strategies and international standards (e.g., ISO 16000, WHO guidelines) for assessing and managing hospital air pollution are reviewed. Effective risk assessment and mitigation strategies are essential to minimize exposure and enhance air quality, ensuring a safer healthcare environment. The integration of proper ventilation, pollutant source control, and adherence to IAQ standards is crucial in reducing airborne health risks. This chapter underscores the need for comprehensive policies and monitoring frameworks to improve IAQ in hospitals, protecting vulnerable populations from harmful exposure.

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Prasath, S., Palaniappan, K., Chan, S.

Characterizing workplace exposures to nano-TiO2 in Singapore: potential risks and mitigation strategies.

Annals of Work Exposures and Health, (2025)

Engineered nanomaterials (ENMs), particularly nano-titanium dioxide (nano-TiO2), are widely used across industries in Singapore, raising concerns about potential worker exposure. This study aimed to quantify occupational exposures and emissions at workplaces handling nano-TiO2, assessing work practices, usage patterns and workplace controls.Occupational exposure to nano-TiO2 was assessed across 7 workplaces (laboratories, manufacturing, downstream application, and recycling). Methods for characterizing personal exposure included personal gravimetric sampling (NIOSH 0600), elemental analysis (NIOSH 7300), and scanning electron microscopy (SEM), while real-time particle number

concentration (PNC) monitoring was done to understand the particle distribution in the workplace environment during the tasks performed. Workplace observations included measurement of dimensions of the work area, existing control measures (engineering, administrative, and personal protective equipment), nature of nano-TiO2 handling practices, forms, quantities, particle size, and state changes of the nano-TiO2 used.Personal exposure samples were collected from 30 workers across workplaces. These include: 7 in laboratory, 10 in manufacturing, 6 in spraying, and 7 in shredding/recycling. Of these, 3 samples, collected during bulk loading and spraying activities, exceeded the NIOSH recommended exposure limit (REL) for ultrafine nano-TiO2 (0.3 mg/m3). Electron microscopy analysis of the samples exceeding the NIOSH REL for ultrafine nano-TiO2 during spraying revealed that the nano-TiO2 particles were predominantly in the size range of 80 to 147 nm. Respirable dust concentration and PNC were positively correlated for higher-risk activities, with peak PNC observed at the workplaces where spraying applications were performed.To our knowledge, this is the first study evaluating nano-TiO2 workplace exposure in Singapore. Exposure levels were generally low, likely due to prevalence of small-scale and research-based applications but varied significantly across workplaces for activities such as spraying, bulk loading and manufacturing. Singapore's current regulatory approach (TR 73) establishes exposure limits but lacks specific guidance on control measures. A more holistic regulatory framework is needed, providing tailored recommendations for diverse workplace exposure scenarios.

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Trujillo Alvarez, D. Y., Orrego Herrera, V.

Condiciones de seguridad y salud laboral en barberías: Revisión de literatura . (Conditions de sécurité et de santé au travail dans les salons de coiffure : revue de la littérature).

Unidad Central del Valle del Cauca Facultad de Ingenierías . Especialización en Seguridad y Salud en el Trabajo

El presente estudio tuvo como objetivo realizar una revisión sistemática de literatura sobre las condiciones de seguridad y salud presentes en las barberías, con el propósito de identificar factores de riesgo, describir condiciones laborales y proponer medidas de control. La investigación se llevó a cabo bajo un enfoque descriptivo y exploratorio, usando la metodología PRISMA-P para la selección de artículos.

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Hou, Z., Chen, H., Zhang, N.

Devil particles: Air pollution and safety liability accidents.

Energy Economics, Vol. **151**, (2025)

This study empirically investigates the causal effect of air pollution on safety liability accidents. Based on the China Stock Market & Accounting Research (CSMAR) database, we compiled detailed information on 5873 safety liability accidents that occurred in China between 2000 and 2020. Using thermal inversions as an instrumental variable and applying a two-stage least squares (2SLS) regression model, our analysis reveals a significant positive impact of air pollution on safety liability accidents. Specifically, a doubling of PM2.5 concentration is associated with approximately a 2.6-fold increase in the probability of safety liability accidents, a 37 % rise in fatalities, and a 51 % increase in total casualties. This effect is particularly pronounced in energy-intensive industries such as coal mining and construction. Further cost estimation suggests that safety liability accidents caused by a doubling of PM2.5 concentration may result in social and economic losses ranging from approximately 4.92 billion to 10.1 billion USD. Mechanism analysis suggests that air pollution may significantly increase the risk of safety liability accidents through multiple pathways, including prolonged exposure duration, altered production behaviors, immediate environmental disruptions, and adverse effects on workers' physical and mental health.

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Budnarowska, K., Pielaszewska, M., Marć, M.

Different approaches, but one goal – An overview of various methods adopted to perform the human health risk assessment regarding to chemical pollutants in indoor environment.

Trends in Environmental Analytical Chemistry, Vol. **48**, (2025)

Exposure assessment is a key element of environmental research because it examines the interactions between people and environmental factors that may pose health risks and affect health conditions. Key compounds for assessing indoor air exposure include particulate matter (PM) such as PM10 and PM2.5, representatives of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), inorganic pollutants, as well as microbial pathogens. Determining the routes of exposure—whether through inhalation, skin contact, ingestion, or absorption through mucous membranes—is critical to assess the potential health effects. Accurate exposure assessment is important for identifying health hazards and developing regulations and protective measures. This paper provides a review of, comparison of traditional sampling techniques with newer, non-conventional approaches (sensors application and individual silicone samplers). The essential element of this work is the collection of current literature information on different types of approaches to assess the degree of exposure of occupants of enclosed areas to harmful chemical compounds present in different types of indoor environments – household or work environments. In addition, a summary of current legal regulations concerning monitored parameters, sampling techniques used, and methods applied to estimate health risks was also presented. It was observed that in most cases the level of exposure of users to harmful chemical compounds was estimated based on the determined total levels of a specific group of compounds such as sum of organophosphate flame retardants (FRs), polycyclic aromatic hydrocarbon (PAHs) or polybrominated diphenyl ethers (PBDEs). A more detailed assessment of the human exposure level was performed in the case of the determination of individual VOCs like benzene or xylenes and trace elements such as Cd and Ni.

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Liu, J., Wang, Y., Ji, W.

Formaldehyde pollution characteristics and health risk assessment of workers during indoor renovation.

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

Indoor formaldehyde pollution originates primarily from the building materials used during interior renovation. However, existing research has largely focused on indoor environments after renovation, while limited attention has been paid to pollutant characteristics during renovation and to renovation workers. To evaluate the health risks associated with formaldehyde exposure among workers involved in residential renovations, over 1130 formaldehyde concentration samples were collected in Beijing, covering five typical stages of renovation: demolition, putty, wall-paint, carpentry, and furniture. Monte Carlo simulations were used for the risk estimation. We found peak formaldehyde concentrations during the carpentry and furniture stages, reaching 89 and 91 μg/m³, respectively, both exceeding the Chinese indoor air quality standard limit of 80 μg/m³. The average cancer risks during the wall-paint, carpentry, furniture stages, and the entire renovation process all exceeded the cancer risk threshold of 10^{-4}. The highest cancer risk was observed during the furniture stage, at 1.35×10^{-4}. Regarding non-cancer risks, the average values exceeded the threshold of 1 in all stages except for demolition. The highest values were observed during the furniture and carpentry stages, with exceedance rates of 88 % and 89 %, respectively. The disability- adjusted life-years (DALYs) were used to estimate the disease burden attributable to formaldehyde exposure, which was the highest in these two stages, with average values of 25 and 24 DALYs per 100,000 population, respectively. In addition, formaldehyde concentrations were significantly and positively correlated with indoor temperature and window-closure duration. This study identified the high-risk stages and key factors influencing formaldehyde exposure during renovations.

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Rey-Álvarez, B., Sánchez-Montañés, B., Silvestre, E.

Harmonizing indoor air quality standards across Europe: A comparative analysis framework for building material regulations and public health protection.

Building and Environment, Vol. **288**, (2026)

Indoor air quality (IAQ) regulation across European Union Member States exhibits significant fragmentation, creating unequal health protection for populations spending 80–90% of their time indoors. This study develops a novel three-dimensional comparative framework to systematically evaluate IAQ regulatory approaches across seven European jurisdictions, focusing on construction material emissions and sustainable building integration. Methods We created an analytical matrix comprising nine quantitative indicators across Scientific Rigor, Implementation, and Innovation dimensions. Seven case studies were analyzed: Germany, France, Finland, Belgium, Italy, Spain, and EU-LCI framework, using standardized evaluation criteria (0–5 scale) for EU-LCI alignment, vulnerable group protection, enforcement mechanisms, and life cycle assessment integration. Results Significant regulatory disparities emerged, with formaldehyde limits varying 300% between countries (10 μg/m³ in France vs. 100 μg/m³ in EU-LCI). Germany achieved highest performance (43/45 points) through comprehensive scientific rigor, while France excelled in innovation (15/15 points) via mandatory emission labeling. Finland demonstrated methodological leadership with dynamic emission parameters (μg/m²·h). Southern European countries showed critical gaps, with Spain scoring lowest (3/45 points). Key weaknesses include: absence of enforcement mechanisms (71% of frameworks), exclusion of emerging pollutants, limited data transparency, and misalignment between energy efficiency mandates and IAQ protection. Conclusions Results demonstrate urgent need for harmonized EU-wide IAQ standards. We recommend mandatory emission labeling combining French stringency with Finnish methodology, IAQ-LCA integration, and vulnerable population protections. For Spain, priorities include binding formaldehyde limits (<50 μg/m³) and national IAQ observatory establishment. This framework provides a replicable tool for evidence-based policy development toward healthier, sustainable indoor environments.

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Himes, J. R., Lee, M., Carrico, K., Mier, F. A.

Identifying building leakage with unmanned aerial vehicle assisted background oriented schlieren imaging.

Division of Fluid Dynamics Annual Meeting 2025

In 2024, air leakage from structures accounted for approximately 4% of the United States' energy budget. Repairing air leakage points in a building can lead to increased energy efficiency, improved indoor air quality, and overall occupant comfort. The background-oriented schlieren (BOS) technique has been used previously to identify leak points, but these measurements have been primarily constrained to the ground. By attaching a high-resolution camera to an unmanned aerial vehicle (UAV) and utilizing improved optical flow algorithms, UAV assisted BOS imaging provides three-dimensional freedom when locating air leakage points around a building.

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Ganesh, G. A., Sinha, S. L., Panchore, V., Verma, T. N.

Impact of Outlet Vent Configurations on Indoor Environmental Quality, Occupant Comfort, and Energy Efficiency: An Optimisation Study.

International Journal of Automotive and Mechanical Engineering, Vol. **22** n°(4), (2025), 12887 - 12902 p.

The rising demand for building energy and the time spent indoors are driving the need for a sustainable balance between building energy demand and occupant comfort. The detailed analysis of fluid flow, radiation heat transfer, heat load on a radiator, and the comfort of indoor occupants is essential for sustainable buildings. This study numerically evaluates the well-validated 3D empty-room model for energy demand in a cold-climate environment to support occupant comfort. Efforts have been made to optimise the factors affecting occupant comfort and the energy demand of the office room to maintain sustainable

stability. A well-validated 3-dimensional model simulated airflow, heat transfer, and occupant comfort. The study optimises factors affecting comfort and energy use using multi-objective optimisation (MOO) techniques. Outlet vent location significantly impacts indoor comfort, energy, and fluid flow. Indoor environments can be optimised for both energy and comfort, especially in symmetrical indoor spaces. Floor-level vents improve air circulation but have little impact on energy use in cold climates. In symmetrical fluid domains, symmetrical outlet vent placement achieved the lowest objective function value (0.026), with a heat load of 412.27 W, PMV of 0.24, and PPD of 7.12, whereas floor-level outlet vents showed the highest objective function value (0.575), with PMV of 0.51 and PPD of 12.11, indicating reduced comfort. Overall, optimising ventilation strategies allows for prioritising occupant comfort and energy efficiency based on specific needs.

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Ismail, I., Zulkarnain, M. S., Ridzuan, I. S. D., Thamrin, Y., Hamidin, N.

Indoor Air Quality and Sick Building Syndrome in Selected Public Buildings in Shah Alam, Selangor.

Media Kesehatan Masyarakat Indonesia, Vol. **21** n°(3), (2025), 209-217 p.

Indoor Air Quality (IAQ) is always associated with Sick Building Syndromes (SBS) despite the age of the buildings, particularly in buildings where indoor air pollutants may affect occupants' health and productivity. This study assessed IAQ parameters and SBS symptoms in five selected public buildings aged 10 and above in Shah Alam, Selangor. Physical, chemical and biological parameters were measured, while structured questionnaires were completed by 87 respondents occupying the buildings. Most IAQ parameters were within the ranges of the Industry Code of Practice on IAQ (ICOP IAQ 2010), except for air velocity, formaldehyde and Total Volatile Organic Compound (TVOC) in two buildings. Statistical analyses showed no association between the building type and SBS occurrence, and no significant differences ($p > 0.05$) in air velocity, TVOC, CO2 or fungal count among the buildings. In order to reduce SBS risks and enhance SBS, the source of contaminants should be tackled and regular monitoring should be implemented to ensure compliance with IAQ limits.

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Kraus, M., Senitkova, I. J., Machova, P.

Indoor Environmental Quality of Selected Flooring Materials.

Inzynieria Mineralna-Journal of the Polish Mineral Engineering Society, Vol. **2**, (2025)

This study investigates the influence of various flooring materials on indoor environmental quality (IEQ) through a comparative analysis based on in-situ measurements. The primary objective was to assess the concentration of total volatile organic compounds (TVOCs), perceived air acceptability, and odor intensity associated with selected flooring types, specifically wooden flooring, floating flooring, and carpet. The results demonstrated that the highest TVOC concentrations were consistently observed with carpet. However, the lowest air acceptability was recorded for wooden flooring. Notably, when wooden flooring was combined with other materials, improved sorption efficiency resulted in more favorable air acceptability outcomes than the standalone materials. Sensory evaluation of material combinations under in-situ conditions produced more favorable results than those obtained in controlled chamber tests. This suggests that real indoor environments may reduce or moderate the perceived effects of chemical emissions. Over a 36-hour monitoring period, TVOC concentrations from in-situ measurements exhibited a decreasing trend, whereas chamber test concentrations stabilized at higher levels after approximately 18 hours. After 36 hours, TVOC levels from in-situ measurements were lower than those from chamber tests for both standalone and combined flooring materials. Floating flooring demonstrated the lowest TVOC emissions and the most favorable air acceptability and odor intensity, suggesting that it provides an optimal balance between chemical emissions and sensory comfort. The findings underscore the need to complement chamber-based assessments within in-situ evaluations. Real indoor environments introduce variables — such as ventilation rates, humidity levels, and material interactions — that can significantly influence the

emission behavior of materials and how these emissions are perceived. Without considering these contextual factors, indoor environmental quality assessments may overlook key aspects of real-world performance.

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Bahrami, A., Haghighat, F., Zhu, J., Niu, J.

Influence of Residence Time on the Particle-Gas Partitioning of Phthalates onto Airborne Inorganic Particle.

Atmospheric Environment, (2025)

In indoor environments, the presence of particulate matter promotes SVOCs volatilization, increasing their overall concentration in the air. This effect arises from the partition of SVOCs between the gas and particulate phases. The particle/gas partition ratio (Kp) is a critical parameter influencing the fate, transport, and human exposure to indoor SVOCs. Air exchange rate (AER) is a pivotal factor in closed spaces as it regulates the residence time of airborne SVOCs in an indoor environment. It has been reported that AER (or residence time) can affect particle-gas partitioning behavior for organic particles when equilibrium between gas and particle phases is not reached; however, its effect on inorganic particles has not been thoroughly investigated. This study develops an experimental procedure to measure Kp of Di-n-butyl phthalate (DnBP) and Diethyl phthalate (DEP) with inorganic sodium chloride (NaCl) particles. Results shows that DnBP had higher Kp values than DEP. Positive correlation of Kp values and mixing time was observed. These findings are consistent with model predictions. Further experiments were carried out to study the impact of AER on Kp, and the results shown that higher air exchange rates (lower residence time) result in lower particle-phase concentrations of SVOCs due to increased dilution and reduced interaction time with particles. These findings have important implications for indoor air quality assessments, highlighting the influence of ventilation strategies on SVOCs behavior in indoor environments.

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Rajput, S., Mulla, A., Kazi, R., Bargir, S., Chikkodi, T.

Iot-based air pollution monitoring and purification system.

International Research Journal of Engineering and Technology (IRJET), Vol. **12** n°(10), (2025)

This research presents the development of an intelligent air quality management system that leverages Internet of Things technology to monitor and improve indoor atmospheric conditions. The proposed solution addresses growing concerns about airborne pollutants in enclosed spaces by implementing real-time detection and automated purification. At the core of the system is an ESP32 microcontroller that processes data from multiple environmental sensors, including a GP2Y1010 particulate matter detector and an MQ135 multi-gas sensor. These components work in tandem to identify harmful substances such as dust particles, carbon dioxide, carbon monoxide, and benzene derivatives. The architecture incorporates dual-mode operation, allowing either manual control through a mobile application or automatic adjustment of purification intensity based on contaminant concentration. Experimental validation demonstrates the system's capability to maintain air quality within safe parameters by dynamically modulating fan velocity in response to pollutant levels. This approach represents a significant step toward creating healthier indoor environments through accessible smart technology.

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Pang, Z., Guo, M., O'neill, Z., Smith-Cortez, B., Yang, Z., Dong, B.

A longitudinal field study of sensor-driven occupancy-centric HVAC controls in an office building.

Energy and Buildings, Vol. **351**, (2026)

Occupancy-centric controls (OCCs) have demonstrated significant energy-saving potential in building Heating, Ventilation, and Air Conditioning (HVAC) systems, yet existing research has been predominantly

focused on computer simulations or limited-scale field testing due to the paucity of suitable occupant counting sensing products, interoperability issues between sensor technologies and building automation systems (BAS), and the technical complexities associated with modifying existing control sequences within BAS frameworks. This paper presents a longitudinal field investigation of occupancy-centric HVAC controls conducted in a real-world office building situated in the southern United States over an extended 13-month period. A network of floormat-based occupant counting sensors and passive infrared (PIR) based occupancy presence sensors was integrated with the BAS using Internet of Things (IoT) technology to facilitate the implementation of comprehensive zone and system-level temperature and ventilation reset control sequences. The whole-year field test indicated substantial energy savings, achieving a 55.47% reduction on weekends and holidays and a 43.48% reduction on workdays, without compromising indoor thermal comfort or air quality. The sensor demonstrated high accuracy for a significant portion of the time, particularly in low-occupancy scenarios, while there was a sharp increase in larger errors for very high occupancy scenarios. This research advances building automation through three key innovations: first, a pioneering implementation of building-wide occupancy sensing with direct BACnet integration into existing BAS infrastructure, addressing the critical gap between sensing and control systems. Second, it demonstrates a pioneering real-world deployment of comprehensive PPCL-based occupant-centric control strategies that bridge theoretical frameworks with practical industry standards. Third, it introduces a novel longitudinal analysis framework that quantifies the interplay between sensor errors and control performance, providing insights into the robustness of sensor-driven building controls. These contributions establish a foundation for scalable, robust occupant-responsive building systems.

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Alkakuri, M., Elkhouly, A., Jaafar, K., Gouda, H.

A Machine Learning Approach to Predicting Air Quality and Health Risks for Construction Worker Safety.

Aerosol and Air Quality Research, Vol. **25** n°(12), (2025), 65 p.

Air quality at construction sites significantly impacts workers' health and safety. This study investigates the application of machine learning models to monitor and predict air quality while assessing health risks associated with construction activities. Data was collected indoor during peak construction phases from three sites: a 35-story apartment building, a two-floor villa, and a townhouse for comparison and evaluation. Advanced air quality monitors measured key pollutants. The data was pre-processed by addressing missing values, removing outliers, and normalizing to ensure it accurately reflects the air quality. Decision Tree regression and other classification models were used to predict pollutant trends and assess associated health risks. The regression models demonstrated high predictive accuracy, with R-squared values exceeding 0.95 for different pollutants across used datasets. The classification models achieved over 91% accuracy in estimating health risks based on pollutant thresholds. The Emirati Air Quality Index (EAQI) identified poor air quality especially at the high-rise site. Test Data was collected from a new site, townhouse construction site was used to test the model, confirming its robustness with prediction accuracies of 88% for PM1.0 and 96% for PM2.5, however variability was observed in the values for CO2 and PM10. Pollutant levels were higher at high-rise sites emphasizing the need for targeted mitigation. This study confirms the feasibility and importance of utilizing predictive models for effective air quality monitoring and managing health risks at construction sites.

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Arcamone, G., Luo, Y., Lo Verso, V. R. M., Favoino, F., Pellegrino, A.

Monitoring infrastructure for occupant well-being and comfort in a Living-Lab: a focus on wearable devices.

Journal of Physics: Conference Series, Vol. **3140** n°(12), (2025)

Today, building design focuses on optimizing indoor environmental quality (IEQ) and ensuring the comfort and well-being of occupants. In this context, a continuous monitoring infrastructure can provide the

necessary data to ensure that the environment adapts proactively and in real-time to the occupants' needs. This approach, applied in a research context, requires the simultaneous monitoring of three levels of measurement: objective-environmental parameters, using lab-grade instruments in the environment and wearable devices; subjective-psychological parameters, obtained through questionnaires and cognitive tasks; and physiological parameters, gathered via wearable devices. This paper presents a 3-layer monitoring infrastructure and its first demonstration use case, conducted in Politecnico di Torino for two weeks in March 2025. The aim is to investigate whether wearable sensors can provide objective insights into a deeper understanding of the relationship between IEQ and occupants' comfort and well-being. Some preliminary findings are discussed, along with a review of the state of the art in wearable technologies across the four environmental domains, and the rationale behind the selection of specific devices.

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Asbagh, G. B., Jafari, M., Ranjbar, F., T. Shervani-Tabar, M., Sojoudi, A.

Optimization of air curtain parameters for enhanced indoor air quality.

Next Research, Vol. **3**, (2026)

Air curtains limit heat and contaminant ingress by forming a high-speed airflow barrier across openings. Using CFD with the k–ω SST model, the minimum jet exit velocity of air curtain required to prevent CO_2 from entering the breathing zone is determined for free-jet and wall-jet configurations under varying pressure differences. In both cases, jet width was varied from 0.2 to 0.4 m. For the wall-jet only, wall length (0.5,1,2 m) and wall angle (−5 to +15 degrees) were examined. The model is validated against reference-free and wall-jet data with an error below 4 %. When the mass flow rate is constant, increasing jet width from 0.2 to 0.4 m reduces jet velocity, decreasing momentum flux and consequently reducing the air curtain's ability to block CO_2 dispersion. Extending wall length from 0.5 to 2 m reduces the minimum required velocity by approximately 22 %, while maintaining the air curtain's effectiveness, whereas wall-angle changes have a negligible effect. This work provides a coupled parametric map linking jet width, wall length, and wall angle to the minimum jet velocity and breathing-zone CO_2 concentration, which has not been previously reported. By adjusting various parameters, the velocity can be minimized while maintaining the air curtain's effectiveness.

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Mohammed, R. H., Tilghman, M. B., Van Dixhorn, L. R.

Performance evaluation of a thermal driven liquid desiccant DOAS integrated with CHP system.

Energy Conversion and Management, Vol. **348**, (2026)

Conventional electrically driven air-conditioning systems face inherent limitations in moisture management and impose substantial energy demands, leading to compromised indoor comfort and elevated operational costs. A thermal-driven liquid desiccant air conditioning system that separates sensible and latent cooling offers a promising alternative by enabling precise humidity control, improved indoor air quality, and energy savings. When coupled with waste heat utilization, this strategy further enhances energy resilience by reducing reliance on grid electricity and improving overall building performance. This study investigates the techno-economic feasibility of a novel Liquid Desiccant Dedicated Outdoor Air System (LD-DOAS) driven by waste heat recovered from a micro-Combined Heat and Power (mCHP) unit. The LD-DOAS integrates a desiccant-based indirect evaporative cooler, a waste-heat-driven regenerator, and a thermochemical energy storage tank. The mCHP unit simultaneously supplies thermal energy for desiccant regeneration and electrical energy for building loads, optimizing energy utilization and enhancing resilience during grid disruptions. An experimental test rig was developed to characterize the regenerator's performance under varying operating conditions, enabling detailed energy flow analysis. A comprehensive energy-cost model was constructed, and results show that the integrated LD-DOAS/mCHP system achieves seasonal energy efficiencies exceeding 75% across diverse climatic regions. Comparative analysis using a dew-point bin-weighted method indicates potential reductions in seasonal energy costs of up to 75% and CO2 emissions of up to 67% compared to conventional electric DX-DOAS systems. These findings underscore the viability

of using natural gas to power the LD-DOAS/mCHP system, enabling efficient cooling, dehumidification, and electricity generation while enhancing building energy resilience and humidity control, particularly in humid climates.

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Onyejizu, J., Karlicek, R. F.

Poster Abstract: Dynamic Graph Learning for Multizone Indoor CO_2 Prediction.

Proceedings of the 12th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation.Colorado School of Mines, Golden, CO, USA

Accurate forecasting of indoor CO2 concentrations is critical for demand-controlled ventilation and maintaining healthy air quality in buildings. In multizone settings, prediction is complicated by dynamic airflow patterns arising from occupant movement, door usage, infiltration, and ventilation schedules. We propose a spatiotemporal learning framework that combines a schedule-gated, infiltration-aware Graph Convolutional Network (GCN) with a Long Short-Term Memory (LSTM) decoder to forecast zone-level CO2 up to 24 hours ahead. Each zone is represented as a graph node, with time-varying adjacency reflecting operational connectivity and outdoor air exchange. We evaluate the model on simulations of a five-zone office prototype driven by real weather, ambient CO2, and stochastic agent-based occupancy. The proposed dynamic graph model consistently outperforms an independent LSTM baseline across all horizons, reducing 24-hour RMSE by 23.2% and MAE by 29.4%, while improving R2 by 8.3% relative. These results highlight the benefit of incorporating schedule-aware spatial coupling into multizone CO2 forecasting.

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

Real-time direct measurement of indoor respiratory aerosols.

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

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

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Sistani, F., Sadeghzadeh, S.

Review: laser-induced graphene for high-performance pressure sensors.

Journal of Materials Science, Vol. **60** n°(44), (2025), 21591-21682 p.

Laser-induced graphene (LIG) has emerged as a transformative material for advanced pressure sensors, uniquely bridging the gap between high performance and manufacturability. Its direct-write, single-step fabrication under ambient conditions sets it apart from other nanomaterials like CNTs and MXenes, offering

an unparalleled blend of cost-effectiveness, scalability, substrate versatility, and high performance. This review examines the mechanisms, fabrication techniques, and applications of LIG-based sensors, focusing on their piezoresistive behavior, dynamic bridging effect, and encapsulation strategies for enhanced durability. Optimized laser parameters and micro/nanostructure engineering have significantly improved sensitivity, response time, and detection range. LIG sensors excel in applications such as wearable electronics, health monitoring, and IoT platforms, enabling real-time tracking of heart rate, blood pressure, respiration, tactile sensing, and environmental parameters. Key advancements include rapid response times (< 40 ms), robust long-term performance, and high sensitivity. However, challenges like achieving large-area uniformity, enhancing environmental stability, and advancing miniaturization persist. Future directions emphasize integrating LIG sensors with energy-harvesting systems, dual-function platforms, and AI-driven analytics for smart monitoring. In conclusion, LIG-based pressure sensors present a transformative solution, offering scalable fabrication alongside remarkable versatility and high performance. Their potential to revolutionize flexible, wearable, and intelligent sensing systems positions LIG as a foundational material for next-generation applications.

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Babatope, O. M., Akokodaripon, D. A., Okoruwa, P. O.

Smart Building Technologies: Enhancing Sustainability and Performance.

International Journal of Advanced Multidisciplinary Research and Studies, (2025)

This paper explores the transformative impact of smart building technologies on sustainability and performance in the built environment. It delves into key technologies such as the Internet of Things (IoT), artificial intelligence (AI), automation systems, and smart sensors, examining their roles in enhancing energy efficiency, water conservation, waste management, and environmental monitoring. The paper highlights how these technologies improve operational efficiency, occupant comfort, space utilization, and cost savings, offering substantial returns on investment. Despite the challenges of high initial costs, interoperability issues, and cybersecurity concerns, the paper discusses potential solutions and future trends, emphasizing the importance of policy and regulatory support. Ultimately, adopting smart building technologies is a critical step toward achieving sustainability goals and creating healthier, more efficient, and responsive buildings.

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Real, L. P., Patricio, J., Viegas, J., Pereira, A., Costa, J., Linares-Alemparte, P.

Solutions for Radon Prevention and Mitigation in Buildings.

Journal of Engineering Research and Application, Vol. **5** n°(5), (2025)

Radon (Rn) is the largest natural source of ionizing radiation and exposure to high levels of this gas and its short-lived offspring over prolonged periods can become a public health problem. Radon exists in soils and building materials and can enter buildings by convection through cracks in the envelope or by diffusion through the envelope itself when it is porous, reaching concentrations above the recommended reference levels. The aim of this article is to present the factors that most influence the potential of radon gas in buildings and to indicate the main technological solutions for controlling, reducing and mitigating its effects. Calculations are presented showing that the proper sizing of membranes and ventilation systems ensures indoor air quality, whatever the level of radon in buildings. The conclusions highlight the importance of ventilation technologies in radon reduction systems, as well as their effectiveness in both preventing radon gas from entering and reducing its concentration once it has entered the building. Also noteworthy is the ability of protective barriers to insulate the building envelope, provided they are properly sized with the appropriate mechanical characteristics, with a special focus on installation requirements. Finally, the main future developments are outlined, with a view to ensuring greater sustainability of the materials, products and protection systems used.

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Zhang, L., Ding, Y., Zhu, P., Li, J., Wang, Y., Zhong, W.*, et al.*

Source-driven stratified accumulation and health exposure of VOCs and PFAS in underground commercial complexes.

Building and Environment, Vol. **288**, (2026)

Accelerating urbanization has led to the extensive development of underground commercial complexes (UCCs), where enclosed environments exacerbate air pollution due to limited ventilation and diverse anthropogenic emission sources. This study addresses critical research gaps regarding the contamination characteristics, spatial behavior, and population exposure risks of volatile organic compounds (VOCs) and per- and polyfluoroalkyl substances (PFAS) within a representative Chinese UCC. Through integrated field monitoring and numerically validated simulations, pronounced vertical and spatial variations in multi-pollutant distributions were identified. VOC concentrations on basement level 1 (B1) reached 7.8 times outdoor levels, while distinct functional zones exhibited unique chemical fingerprints: clothing areas were characterized by elevated PM2.5 and styrene, fashion zones by accumulated tetrachloroethylene, and food courts by aldehydes and short-chain PFAS. PFAS profiles further demonstrated clear chain-length dependencies across zones, indicating source-related segregation. Computational fluid dynamics (CFD) simulations illustrated key dispersion and deposition mechanisms, highlighting influences from architectural layout and ventilation conditions. By integrating empirical pollution data with detailed occupant activity surveys, inhalation exposure levels were quantitatively assessed across population groups. Significantly elevated risks were identified among long-term workers, particularly in clothing and food zones, where lifetime carcinogenic risks related to tetrachloroethylene and perfluorooctanoic acid (PFOA) reached levels on the order of 10–4. These findings provide new insights into source-specific contamination patterns and population-dependent exposure dynamics in UCCs, supporting the development of targeted risk management strategies for sustainable underground development.

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Laporte, M. C., Mullot, J.-U., Hlal, R., Klerlein, M., Momas, I., Bensefa-Colas, L.

Ultrafine particles and black carbon concentrations and determinants in aircraft cabins of a French airline: Paris-aircraft study.

Environment International, Vol. **206**, (2025)

People are spending increasing amounts of time on airplanes. Nevertheless, few studies have characterized the concentrations of ultrafine particles (UFP) and black carbon (BC) in aircraft cabins, which are particulate pollutants known to have adverse health effects. This study aims to assess indoor air quality by measuring UFP and BC concentrations in aircraft cabins during different phases of flight and identifying the key determinants influencing their levels. This study reports pollutant concentrations measured from the beginning of boarding to the end of disembarkation across 16 European commercial flights conducted on three aircraft types (A220, A319, A321). A phase-by-phase multivariate regression analysis was performed to identify the factors associated to these concentration levels. Average concentrations of 9,122 particles/cm3 for UFP and 207 ng/m3 for BC were observed. Ground phases showed higher concentrations than in-flight phases, with levels decreasing after take-off and increasing again during descent (UFP) and after landing (UFP and BC). The analyses of determinants revealed: (1) a decrease in UFP levels with longer cruise duration; (2) an increase in both UFP and BC levels during extended taxiing; (3) higher BC levels with a greater number of passengers; (4) specific aircraft types elevated UFP levels during climb and descent; (5) a lack of association with altitude, turbulence events, or duration of meal service. Measured levels showed much lower concentrations of these pollutants compared to other modes of transport. Cabin concentrations of UFP and BC appeared to be primarily driven by outdoor sources, particularly those related to airport ambient air pollution.

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Kamoliddin, K., Tukhtashev, A., Mansur O‘G‘Li, X. B.

Utilizing methods of ventilation system management in industrial enterprises to balance loads.

AIP Conference Proceedings, Vol. **3331** n°(1), (2025)

Electric energy plays a crucial role in modern life, but the growing demand for consumption turns energy management into one of the pressing issues of the 21st century. This article examines the methods of using electric energy in industrial enterprises. The analysis focuses on the most energy-consuming devices and systems within industrial enterprises, particularly the various strategies for managing HVAC systems. The study describes methods for reducing energy consumption, saving costs, and improving overall efficiency through the application of different management techniques. This research creates the possibility of significantly reducing energy consumption in industrial enterprises by implementing new and effective energy management methods.

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