Bulletin de veille QAI
N°10-2025

Objectif : *Qualité de l'air intérieur*

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Google Scholar, Lens, WoS

Gurram, R., C. S, N., A, B., T, M.

Adaptive Indoor Air Quality Monitoring System using Iot Sensors And Deep Learning.

2025 International Conference on Innovations in Intelligent Systems: Advancements in Computing, Communication, and Cybersecurity (ISAC3). 25-26 July 2025. Bhubaneswar, India

Air pollution is a major risk to public health and environmental sustainability. This paper introduces an IoT-based air quality monitoring system that uses deep learning to offer real-time pollution evaluation. The system incorporates several gas and particulate matter sensors, such as MQ-7, MQ-135, MQ-4, a PM2.5 dust sensor, and a temperature sensor, to gather environmental information. The ESP32 controller sends the reading from sensors to a cloud portal (Blynk), on which there exists a learned deep learning model with three output classifications: good, moderate, and bad" The determined status is updated on an LCD display screen and gives instantaneous visible feedback together with actionable tips in the form of air is clean!, stay cautious!, or avoid outdoors!. It keeps getting refreshed in real time, keeping up with the real-time pollution measurement. Experimental outcomes prove the efficiency of the model in detecting air quality status, which is an indication of its suitability for wide-scale application. This study advances the construction of low-cost, smart air monitoring systems that can support public awareness and decision-making towards healthier surroundings.

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Pang, D., Tian, E., Xie, R., Yin, Z., Chen, J., Deng, J.*, et al.*

Advances and challenges in metal oxide semiconductor-based sensors for indoor ozone detection.

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

Precise ozone (O3) monitoring is critical for human health, building environment, medical sterilization, and industrial process control. Metal oxide semiconductor (MOS)-based sensors offer high sensitivity and easy miniaturization, making them attractive for O3 detection, particularly in building and indoor air quality systems. Despite significant progress, a comprehensive analysis encompassing the fundamental sensing mechanism, material structure-property relationships, and performance enhancement strategies remains lacking. This review comprehensively elucidates the fundamental sensing mechanism of MOS-based O3 sensors, including interfacial O3 adsorption, charge transfer, and conductivity modulation. It also evaluates key performance metrics and the influence of environmental factors such as operating temperature, humidity, and lighting. Crucially, the correlations between material composition, microstructure, and sensing properties are analyzed to guide rational material design for robust performance in real-world applications like indoor monitoring. The development of gas sensor structures, from traditional sensors (sintered, thick film, and thin film types) to micro-electro-mechanical systems (MEMS) sensors and flexible sensors, was analyzed. Finally, emerging research directions aimed at improving sensitivity, lowering energy consumption, and enhancing operational stability for long-term indoor deployment are identified. These insights aim to support the development of next-generation MOS-based O3 sensors for real-world applications.

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Simu, S., Turkar, V., Martires, R., Asolkar, V., Monteiro, S., Fernandes, V.*, et al.*

Air pollution prediction using machine learning.

Journal For Research in Applied Science and Engineering Technology, Vol. **13** n°(8), (2025), 231-236 p.

Predicting air pollution levels is crucial because of the damage it may do to ecosystems and people\'s health. A comprehensive review of current methods and models for forecasting air pollution has been presented in this article. A thorough review of 32 scholarly publications explores various machine learning algorithms, statistical models, and hybrid approaches to predict future pollution concentrations accurately. We discuss the unique challenges of air quality prediction, including data variability, spatial-temporal correlations, and the effect of meteorological factors. The research divides existing prediction models into categories based on their methodologies, data requirements, and application scenarios, stressing their strengths and limitations. The study also looks at how new technologies like IoT sensors, deep learning, and ensemble techniques might improve the precision and dependability of air pollution predictions. Future research focuses on integrating real-time data, multi-source information fusion, and developing scalable, interpretable models for dynamic air quality management.

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Abdellatif, Y. M., Surkatti, R., Muhammad, R., Sodiq, A., Nassar, N., Al-Ansari, T.*, et al.*

Amine free direct air capture integrated with buildings' cooling systems in humid environments.

Energy Conversion and Management, Vol. **347**, (2026)

Direct air capture, among the negative emission technologies, is well positioned to reach climate goals. However, adsorption-based direct air capture system faces significant challenges in humid environments due to water-CO2 co-adsorption, which substantially increases thermal regeneration energy requirements and negatively impacts overall efficiency. To overcome this problem, this study presents novel direct air capture systems integrated with air handling units incorporating a silica gel wheel to dehumidify air before the adsorption process. Dehumidification of air by integrated silica gel wheel enhances the performance of physisorbents and chemisorbents such as NbOFFIVE, Zeolite-13X, SBA-15 functionalized with tetraethylenepentamine, SBA-15 functionalized with L-PEI, and Lewatit by reducing moisture, thereby improving CO2 capture efficiency in humid environments. After capture, saturated part of silica gel wheel meet the moisture-free airstream and regenerate the water without heating and raising the stream humidity approaching the desired indoor humidity levels. The findings presented are supported by both experimental work and mathematical models. This integration significantly reduces thermal regeneration energy requirements by 82 % for NbOFFIVE and 39 % for SBA-15 with tetraethylenepentamine compared to non - silica gel wheel configurations. Moreover, compared to operating direct air capture and heating, ventilation, and air conditioning systems separately, in which their combined thermal energy is 304.73 kWh/day, the integrated system consumes only 128.52 kWh/day of thermal energy, cutting total thermal energy use by 57.8 %. Even against heating, ventilation, and air conditioning system alone (149.08 kWh/day), it achieves a thermal energy saving of 13.8 %.

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Gobbi, M. E.

Analysis of indoor air emission limits assessed in environmental building certifications.

IOP Conference Series: Earth and Environmental Science, Vol. **1536** n°(1), (2025)

The issue of air quality in the outdoor and indoor environments of buildings has been addressed for a few decades, but has once again come to the force, this time for health and sanitation reasons. In recent years, the world has faced the COVID-19 pandemic. Air quality improvements can be achieved not only with good architectural design, but also with a good selection of materials and construction methods. The aim of this article is to investigate how environmental certifications for buildings address indoor air quality (IAQ) criteria, taking into account which classes of pollutants are commonly assessed. To achieve the proposed aim, the categories of 'building materials' and 'air quality' were analyzed in the environmental certifications with the largest number of certified buildings in Brazil (LEED, AQUA-HQE and BREEAM). In addition to these, the certification focused on health and well-being for building occupants, i.e. the North American WELL certification, was also analyzed. As a result, the four certifications presented similar emission limits for two types of pollutants common in building materials: total volatile organic compounds (TVOC) and

particulate matter (PM 2.5µ and PM 10µ); and differed considerably in terms of formaldehyde emission limits in all certifications. It was possible to conclude that there is a lack of harmonization of information on pollutant emission limits for IAQ in buildings through the certifications researched; as well as the lack of national legislation that serves as a parameter for establishing acceptable limits.

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Aslam, M. M., Tufail, A., Gul, H., Irshad, M. N., Namoun, A.

Artificial intelligence for secure and sustainable industrial control systems - A Survey of challenges and solutions.

Artificial Intelligence Review, Vol. **58** n°(11), (2025)

In modern industrial environments, the security and sustainability of Industrial Control Systems (ICS) have become crucial. This comprehensive review examines the transformative potential of Artificial Intelligence (AI) in ICS, focusing on technologies like Machine Learning (ML), Deep Learning (DL), Large Language Models (LLMs), and cloud computing. Moreover, this research explores integrating existing and proposed sustainable practices within the ICS framework, with a particular emphasis on energy efficiency and carbon footprint reduction, to enhance the overall sustainability of ICS. This review employed a systematic approach to select relevant articles from multiple reputable databases, such as Scopus, IEEE Explore, Science Direct, ACM digital library, Web of Science, and IET digital library, including 250 articles that provide valuable insights into the intersection of AI, security, and sustainability in ICS. This review examines vulnerabilities in ICS, such as data breaches, insider threats, and malware, emphasizing the need for effective anomaly detection. It highlights how AI technologies like anomaly detection and predictive analytics can enhance threat detection and response in ICS by improving accuracy and efficiency. The review offers insights to researchers and professionals on the future of secure, sustainable ICS, supporting a resilient industrial landscape that meets cybersecurity, compliance, and sustainability goals.

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Verzeroli, M., Gaioni, L., Lazzaroni, P.

Assessing Low-Cost PM and MOx Sensors for Enhanced Outdoor Air Quality Monitoring.

2025 IEEE Sensors Applications Symposium (SAS)

A low-cost air quality station has been developed to investigate the use of metal-oxide sensors in outdoor air quality assessment. This study presents the results of an outdoor measurement campaign conducted in Dalmine, Northern Italy, for 67 days. The station was equipped with an optical particle counter for particulate matter (PM) measurements and metaloxide (MOx) sensors for volatile organic compounds (VOCs) detection. Measurements were compared with data from a fixed reference station operated by ARPA Lombardia. The PM sensor exhibited a strong correlation with reference values, although relative humidity influenced measurement accuracy. Additionally, MOx sensor signals demonstrated a moderate inverse correlation with PM2.5 concentration, highlighting their potential for qualitative air quality assessment. A linear regression model was applied to analyse this correlation, considering environmental factors such as absolute humidity. The results suggest that low-cost MOx sensors can complement traditional air quality monitoring systems and could be leveraged in future IoT-based environmental monitoring applications.

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Mohd Noor, N. H., Mohd Nor, N.

Assessing the Influence of Organisational Factors on Civil Servants' Performance at Malaysian Immigration Department, Putrajaya.

International Journal of Management and Human Science (IJMHS), Vol. **9** n°(2), (2025), 01-10 p.

Background: Employees are an asset for an organisation. Quality employees will indirectly increase the productivity of the organisation. On the other hand, employees who have problems in their jobs can cause harm to the organisation. The performance of civil servants in Malaysia is one of the matters that the current government fully emphasises. Work performance and the quality of services delivered are very significant in the context of the public service. Objective: The aim of the study is to examine the factors influencing job performance among Malaysian Immigration Department staff. Methods: The study focuses on three factors: work conditions, office layout, furniture equipment, and management support. The study uses a cross-sectional survey, and the data were obtained through a questionnaire distributed to 150 respondents at the Malaysian Immigration Department in Putrajaya. This questionnaire was produced based on previous studies. The data was analysed using the Statistical Package for Social Science (SPSS). The Likert scale examines how strongly the respondents agree or disagree with the statement The statistical analysis used was descriptive, Pearson correlation, and multiple linear regression. Results: The study findings showed that work conditions, office layout, furniture and equipment, and management support positively correlate with job performance. Second, work conditions are the most significant predictor of job performance. Conclusion: Changes in aspects of the work environment for the better, especially involving aspects of the physical environment such as employee efficiency, good employment relations at the workplace, implementing aspects of occupational safety and health, and creating a safe work culture, will certainly guarantee employee commitment and improved performance.

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Chen, J., González, Ó., O'connor, D., Tallon, L., Pilla, F.

Assessment of IoT low-cost sensor networks for long-term outdoor and indoor air quality monitoring: a case study in Dublin.

Atmospheric Pollution Research, Vol. **16** n°(11), (2025)

This study provides a framework for Internet of Things based low-cost sensors (LCS) network implementation, using office environments in Dublin, Ireland, as a case study for long-term indoor air quality (IAQ) monitoring. It covers options and key decisions related to sensor technology, reporting systems and data management. Environmental and indoor data were collected from 1 June 2023 to 20 June 2024, using Smart Citizen Kit 2.1 and PurpleAir devices, and data retrieved from cloud-based data platforms for analysis. The standard deviation and coefficient of variation were calculated to evaluate intra-sensor precision. To improve data quality of LCS various correction models were tested, considering the impact of temperature and relative humidity. A multilinear model with additive relative humidity, using the piecewise regression, provided better performance (R2 > 0.7, RMSE <5 µg/m3) and accuracy (>0.88) for 24-h fine particulate matter (PM2.5) and inhalable particulate matter (PM10). This study bridges the data gap by incorporating multi-brand LCS network for further application in outdoor supplementary and IAQ reporting. The results showed corrected indoor PM2.5 data in offices complies with WHO air quality guidelines, and carbon dioxide (CO2) levels in naturally ventilated conditions remained below 800 ppm. Additionally, diurnal patterns reveal elevated levels of CO2 and total volatile organic compounds during core office hours, while the contrasting patterns for PM2.5 suggest outdoor infiltration as the dominant source. This study demonstrates the potential of data-driven techniques for real-time IAQ monitoring and reporting, providing valuable insights to promote healthier IAQ for occupants.

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Vivekanandan, N., Rajeswari, K., Kanna, N. V. Y.

A CFD-based assessment of Azolla biofilters for sustainable indoor air purification in low-carbon buildings.

International Journal on Interactive Design and Manufacturing (IJIDeM), (2025)

Indoor air pollution is increasing in energy-efficient buildings with restricted natural ventilation that results in pollutant accumulation in the form of carbon dioxide (CO2) and fine particulate matter (PM2.5). Conventional air purifiers are based on energy-consuming mechanical or chemical filtration mechanisms

that are responsible for carbon emissions and maintenance. This research suggests a nature solution employing Azolla, a high-performance photosynthetic aquatic fern that grows rapidly, as a biofilter. A Computational Fluid Dynamics (CFD) model employing Navier–Stokes and advection–diffusion-reaction equations has been employed to model airflow and pollutant transport in an indoor test setup. Simulation yields the depletion of 40% of CO2 and 55% of PM2.5 concentrations within 300 s. These values find favorable validation with past experimental research on green plant systems, e.g., Peace Lily and green vertical walls, confirming the model. The Azolla system only uses 0.1–0.2 kWh/day, providing as much energy up to 90% with reduced carbon footprint compared to traditional HVAC systems. Its photosynthesis activity allows active CO2 capture, which can support potential net-negative emissions. The results justify incorporating Azolla-based filtration in green building design as a sustainable and energy-efficient indoor air cleaning mechanism.

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Xiu, M., Cheng, Y., Liu, S., Huang, Y., Xue, Y., Li, Y.*, et al.*

Characteristics, sources and risk assessment of volatile organic compounds in a subway environment - A case study in Xi'an, China.

Building and Environment, Vol. **283**, (2025)

Volatile organic compounds (VOCs) are ubiquitous, with toxicity that pose risks to human health and the environment. The adverse effects of VOCs could be higher in the subway environment due to possible accumulation because of inadequate ventilation. However, systematic and comprehensive studies on VOCs pollution in subway environments are lacking. This paper investigated the types and pollution characteristics of VOCs in 4 different lines of the Xi'an Subways including carriages, platforms and concourses, aiming to identify the pollution sources, to assess the influencing factors for VOC concentrations, and to evaluate the health risks of VOC exposure. A total of 113 VOCs were detected with propionaldehyde having the highest concentration (39±17 μg/m3), followed by acetone (29±13 μg/m3), acetaldehyde (23±15 μg/m3), methylene chloride (17±24 μg/m3), and formaldehyde (12±40 μg/m3). Several factors, including the number of passengers, subway operation period, and the track position, have been identified to affect the VOC concentrations in carriages. VOC concentrations are decreasing from underground platform > elevated platform > underground concourse > ground platform. Decorative materials, outdoor sources, human body emissions, and cleaning supplies were the main sources of VOCs in subway carriages with human body emissions as the largest contributor (35.42 %). The carcinogenic risk to passengers of formaldehyde (3.86 × 10–5), methylene chloride (1.76 × 10–5), acetaldehyde (1.23 × 10–5), trichloromethane (8.17 × 10–6), 1, 2-dichloroethane (4.82 × 10–6), 1, 2-dichloropropane (3.05 × 10–6) and 1, 3-butadiene (1.08 × 10–6) were above the acceptable risk level (≤10–6). These results provide scientific basis for planning the improvement of the air quality of in subway system now and in the future.

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Keller, F.-X., Robert, L., Klingler, J.

Characterization of emissions generated during additive manufacturing of polymer parts by the fused deposition modeling technique.

Journal of Occupational and Environmental Hygiene, (2025), 1-10 p.

Additive manufacturing has developed steadily since it was first introduced in the 1980s, but it is not without occupational risks. The main objectives of this study were to characterize airborne particle and VOC (Volatile Organic Compounds) emissions generated by a 3D additive manufacturing using polymers and to evaluate the effectiveness of local extraction ventilation as a control measure to reduce emissions. A comprehensive measurement methodology involving direct-reading instruments and active tube air sampling was deployed around and inside the machine. Three polymer materials were studied: ABS (Acrylonitrile Butadiene Styrene), ASA (Acrylonitrile Styrene Acrylate), and PETG (PolyEthylene Terephthalate Glycol). The same test part was fully manufactured three times with each material. During manufacturing, particle number concentrations and real-time VOC profiles, particularly focusing on styrene,

were measured simultaneously. The extraction ventilation parameters on the Zortrax M300 3D printer were recorded and analyzed to assess how they affected pollutant containment and prevention of operator exposure. The number of particles measured for the various materials and their concentration suggest possible operator exposure to airborne particles. Total VOC concentration values were measured from ABS (432.8 µg/m^3), ASA (124.1 µg/m^3), and PETG (4.7 µg/m^3). Real-time monitoring was done for styrene emissions during the manufacturing cycles for the three different materials tested, coupled with VOCs sampling on adsorbent tubes. Use of a local exhaust ventilation system reduced the airborne concentrations between 95% and 99%. It is therefore recommended that 3D printers be placed under an extraction system.

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Wang, B., Yao, Y., Sun, H., Zhao, H., Yu, Q.

Contributions of unknown ionizable precursors for perfluoroalkyl acids in the air over a wastewater treatment plant and a landfill.

Research square, (2025)

Wastewater treatment plant (WWTP) and landfill are important point sources for emission of per- and polyfluoroalkyl substance (PFAS). However, occurrence and risks of emerging and unknown PFAS in the atmosphere of these sources have not been clarified. An optimized novel cartridge-based active air sampler for both neutral and ionizable PFAS was used to collect air samples from a WWTP and a landfill in Tianjin, China. For target PFAS, the concentrations of neutral PFAS were comparable with those of ionizable PFAS in air samples from both sources. 8:2 Fluorotelomer alcohol (8:2 FTOH) was the predominant neutral PFAS in all the air samples, while ultrashort-chain perfluoroalkyl carboxylic acids (PFCAs) were dominant ionizable PFAS. The optimized total oxidizable precursor (TOP) assay indicated that unknown precursors contributed 46.4–58.4 mol%. This study further revealed the unknown PFAS profiles and their risk in the atmosphere contributed by WWTP and landfill.

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Anto, T. R., Gramaje, B. A., Wisniewski, L., Karatzas, S.

Data Management Platform for Indoor Air Quality Management.

2024 IEEE 29th International Conference on Emerging Technologies and Factory Automation (ETFA). 10-13 September 2024. Padova, Italy

This research presents the solution for building a Data Management platform with FIWARE framework and other open-source components to monitor and manage indoor air quality. FIWARE components are used to collect, store, and analyze data related to indoor air quality, such as particulate matter (PM2.5), volatile organic compounds (VOCs), and carbon dioxide (CO2) levels. Other components are used to provide a data registry and data visualizations. To ensure timeliness, the platform enables real-time data collection and processing through FIWARE's Context Broker, allowing immediate updates and access to current IAQ data. The paper presents how such a setup could look like and discusses some open issues related to the data management issue in the indoor air quality context.

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Naddunuri, K., Bhattacharya, S. P.

Deriving Personalized ventilation system performance criteria.

Third International Conference on Energy and Indoor Environment for Hot Climates

Recent research has shown a growing interest in personal environmental controls systems (PECS) and personalized ventilation (PV) systems for enhancing occupant thermal comfort through localized cooling and heating. PV systems offer the potential to create preferred thermal environments and improve perceived air quality through a desk level control. Extensive research has explored PV systems in

conjunction with various ventilation strategies, including mixing ventilation, displacement ventilation, underfloor air distribution, and ceiling mounted air distribution. Significant advancements have been made in recent years through personally controlled environmental chamber experiments using both human subjects and mannequins. The occupant's micro thermal environment under PV influenced by various parameters such as the background ventilation system, supply temperatures, flowrate variation, velocities and control strategies, air terminal device type, and its physical airflow characteristics. A comprehensive understanding of each of these variables is crucial to assess the PV systems performance. Therefore, in the present study, the paper aims to evaluate PV performance based on PV physical configuration, airflow dynamics, occupant health and wellbeing as well as its energy saving potential. The study adopts analytical method to assess the PV system effectiveness under various scenarios and establish performance assessment criteria for comparison until a sophisticated criterion is developed.

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Zhao, X., Yao, Z., Kong, X., Wang, J., Wang, R.

Development of a plasma-based air treatment device for densely populated areas.

Journal of Physics: Conference Series, Vol. **3110** n°(1), (2025)

The persistent challenge of airborne pathogens in densely populated indoor environments calls for efficient and reliable air sterilization solutions. This study presents a compact three-electrode Double Dielectric Barrier Discharge (DDBD) plasma module for sterilizing contaminated airflow, achieving up to 83% microbial inactivation at 9.3 kV and 10.3 kHz. While effective, the plasma discharge produced reactive byproducts, notably ozone (up to 46.21 ppm) and nitrogen oxides (NO_x), at levels exceeding health-based safety thresholds. To mitigate these emissions, a four-stage byproduct control strategy was developed, including a MnO_2 catalytic mesh for ozone decomposition, a UV-activated TiO_2 photocatalytic stage for NO_x reduction and enhanced sterilization, an upgraded 15 mm activated carbon bed for residual adsorption of NO_x and volatile organic compounds, and a feedback-controlled electrochemical sensor to monitor byproduct levels and dynamically adjust plasma power. The modular design facilitates integration into existing filtration frameworks, providing a scalable and practical solution for indoor air treatment in high-traffic settings such as hospitals, schools, and transport hubs.

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Chávez-García, L. E., Sánchez-Badillo, J. A., Espinoza-Herrera, R., Lopez-Albarran, P., Chávez-García, L., Sánchez-Badillo, J.

Development of Oriented Strand Boards Using Leftovers of Veneer-Wood and Non-formaldehyde Lignin or Tannin Adhesive Formulations.

Cureus Journals, Vol. **2** n°(1), (2025)

The urgent need for sustainable construction materials has catalyzed research into formaldehyde-free adhesives for wood composites and the effective valorization of industrial wood residues. This study addresses the growing demand for sustainable alternatives to formaldehyde-based adhesives in the wood composites industry. The present research focuses on developing oriented strand board (OSB) panels using veneer-wood leftovers bonded with two formaldehyde-free adhesives: phenol-lignin-glyoxal (PLG) and phenol-tannin-glyoxal (PTG) resins.

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Jiang, J., Burgholz, T. M., Rewitz, K., Streblow, R., Müller, D.

Development of the CoSIE Lab: An advanced laboratory for multi-domain indoor environmental quality research.

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

Laboratory studies are essential in advancing multi-domain indoor environmental quality (IEQ) research, as they provide highly controllable, precise, and reproducible conditions for investigating the effects of various IEQ factors on occupants' health and behavior. However, many existing IEQ laboratories face significant challenges, including inadequate multi-domain control, limited participant-laboratory interaction, and incomplete performance testing. This paper presents the comprehensive development process of the Comfort Studies and Indoor Environment Laboratory (CoSIE Lab), a flexible and expandable research facility designed to control IEQ factors across thermal, indoor air quality, visual, and acoustic domains. The development process is organized into distinct phases: conceptual planning, design and construction, commissioning and performance testing, and experimental applications. Through this structured approach, we aim to share valuable insights and lessons learned from the development of the CoSIE Lab. Key findings indicate that capillary tube mat is an effective solution for radiant temperature control. In conjunction with a hydronic system, the CoSIE Lab achieves 76 zones with individual surface temperature control ranging from 15 °C to 40 °C. The surface radiant system enhances air conditioning process, enabling both homogenous and heterogenous air temperature distributions within the test rooms. Measurements of illuminance and color temperature demonstrate close alignment with design specifications for artificial lighting as simulated in software. An acoustic assessment reveals potential overestimation of effective absorption areas when applying the DIN EN 12354-6 model for reverberation time calculations. In addition to these findings, this study contributes to enhancing clarity and consistency in research dissemination related to IEQ laboratory developments.

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Pérez Castillo, L. S., López Santana, E. L.

Diagnóstico y Propuesta de Mejora para el Componente Atmosférico Interno y Recurso Agua en la Fabricación de Pellets de la Empresa CARBOCOM CL S.A.S.

Universidad Distrital Francisco José de Caldas. Thèse 2025

This thesis was developed at CARBOCOM CL S.A.S., a company dedicated to the production of smart plastic compounds. The purpose of this thesis was to diagnose and propose improvement alternatives for two critical environmental components: indoor air quality and the efficient use of water resources in the pellet manufacturing process. The methodology implemented was structured in four phases: characterization, diagnosis, document review, and proposal design, integrating field observation, regulatory analysis, and technical calculation tools. In the indoor atmospheric component, five main sources of pollution were identified (calcium carbonate dosing bag, gates and lids, vehicles in operation, dust accumulation, and poor filters), which generate emissions of particulate matter (PM2.5 and PM10), volatile organic compounds (VOCs), and CO_2. Although direct measurements were not possible due to technical limitations, proposals were designed based on the EPA-recommended source control strategy, accompanied by an indoor air quality (IAQ) index model adapted to national and international regulations, to establish reference limits and guidelines for future monitoring. Regarding the water component, the existing infrastructure was characterized, and the demand flow and rainwater harvesting capacity were calculated based on IDEAM rainfall data and hydrological equations. The analysis demonstrated the technical feasibility of implementing a rainwater harvesting and storage system by restructuring downpipes, channels, and connections, with sufficient capacity to supply production and cleaning processes, thus reducing dependence on tanker trucks. The results obtained support the relevance of the proposed proposals, which will contribute to optimizing the company's environmental performance and strengthening its operational sustainability. This work also allowed for the application of environmental diagnostic and technical design tools, consolidating professional competencies in environmental sanitation.

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Salagnac, P., Faure, J.-L.

Efficacité énergétique des bâtiments 1: Enveloppe, ventilation et éclairage.

ISTE Group; 2025.

Ce livre traite successivement le contexte et les enjeux liés au bâtiment, l'enveloppe du bâtiment et les moyens de l'améliorer grâce à des matériaux et des techniques de construction innovants, ainsi que les systèmes de ventilation et d'éclairage.À travers ces différents aspects, l'ambition de cet ouvrage est de fournir au lecteur les outils et les bonnes pratiques nécessaires pour concevoir, rénover ou gérer des bâtiments, afin d'assurer le confort des occupants tout en réduisant l'impact environnemental. Il s'adresse aussi bien aux professionnels qu'aux étudiants en université ou en école d'ingénieur travaillant dans le domaine de l'énergétique du bâtiment.

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Javanjal, V. K., Gadhave, S., Patil, L. N., Mahajan, K. A., Jadhav, S. S.

Efficiency improvement of semi-evaporative cooling systems through environmental analysis.

Sigma Journal of Engineering and Natural Sciences, Vol. **43**, (2025), 1113-1123 p.

This research delves into semi-evaporative cooling systems, exploring their performance in diverse environments with a focus on air supply, temperature, and humidity. Findings highlight the importance of environmental factors, especially the evaporation of ceramic pipe sur-faces. Monthly evaluations of cooling coil loads emphasize the need for consistent system performance monitoring. Optimizing cooling pad thickness can reduce cooling coil load by 29.6%. A triangular design achieves a saturation efficiency of 95%, and mats made from coconut and banana fibers enhance saturation effectiveness. Increasing air intake velocity improves wet bulb efficiency, especially at higher temperatures. The research underscores the pivotal role of relative humidity, showing its impact on chilling capacity. These insights are crucial for designing and implementing semi-evaporative cooling systems in real-world scenarios, offering valuable guidance for system design, operation, and material selection.

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Dang, T.-H., Dang, N.-H., Tran, V.-T.

Efficient IoT indoor monitoring via distributed deep learning in hybrid VLC/RF network architectures.

Internet of Things, Vol. **34**, (2025)

The rapid growth of the Internet of Things (IoT) has driven the demand for efficient indoor monitoring systems that can provide reliable connectivity, low latency, and high energy efficiency. Traditional wireless approaches based solely on radio frequency (RF) suffer from spectrum congestion and interference, while visible light communication (VLC) systems are constrained by line-of-sight requirements and limited coverage. To address these challenges, this paper proposes a hybrid VLC/RF network architecture integrated with distributed deep learning for IoT-based indoor monitoring. In the proposed framework, IoT devices leverage VLC links for high-speed data transmission in favorable conditions and seamlessly switch to RF links to maintain connectivity in non-line-of-sight scenarios. A distributed deep learning framework is deployed across edge nodes to enable scalable and privacy-preserving analytics, reducing reliance on centralized processing while improving adaptability to dynamic indoor environments. Experimental evaluation demonstrates that the proposed system achieves higher monitoring accuracy, reduced latency, and improved energy efficiency compared to single-mode VLC or RF systems. These findings highlight the potential of hybrid communication networks combined with distributed intelligence to enhance the performance and robustness of IoT indoor monitoring applications in smart homes, healthcare, and industrial environments.

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Vishwas, S., Chidambaram, D., Sarkar, M. B.

Enhanced CO2 sensing at low temperatures using Indium-decorated TiO2 nanowire arrays.

Microsystem Technologies, (2025)

This study presents the enhanced carbon dioxide (CO2) sensing capabilities of Indium (In) nanoparticle (NP) decorated Titanium dioxide (TiO2) nanowire (NW) arrays, with a focus on optimizing Schottky diode-based gas sensors for low-temperature operation. Structural and morphological analyses reveal that In decoration significantly reduces the average grain size from approximately 60 nm to ~ 38 nm, thereby increasing surface defect sites and adsorption centers. The fabricated In-decorated TiO2 NW sensor demonstrates a high ideality factor (~ 5.37 at 150 °C), which marginally increases under 200 ppm CO2 exposure, indicating robust charge transport mechanisms. Schottky barrier height is observed to decrease from ~ 1.120 eV (at 150 °C) to ~ 1.088 eV upon gas exposure, suggesting enhanced gas-surface interaction. Most notably, the responsivity of the sensor improves significantly with In decoration, rising from 59 to 98% at 150 °C under reverse bias, highlighting a ~ 3.6-fold enhancement compared to bare TiO2 NWs operating at 150 °C, which exhibits a response of 27.2% at lower reverse bias and 19.7% at higher reverse bias. Moreover, In decorated TiO2 NW sample exhibited high selectivity towards CO2 when compared with H2 and O2. These findings underscore the synergistic effect of one-dimensional nanostructuring and surface decoration in achieving high-performance, low-temperature CO2 sensing.

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Qian, J., Wynn, T., Liu, B., Shan, Y., Bartington, S. E., Pope, F. D.*, et al.*

Enhancing Accuracy of Indoor Air Quality Sensors via Automated Machine Learning Calibration.

EGUsphere, Vol. **2025**, (2025), 1-20 p.

Indoor fine particles (PM2.5) exposure poses significant public health risks, prompting growing use of low-cost sensors for indoor air quality monitoring. However, maintaining data accuracy from these sensors is challenging, due to interference of environmental conditions, such as humidity, and instrument drift. Calibration is essential to ensure the accuracy of these sensors. This study introduces a novel automated machine learning (AutoML)-based calibration framework to enhance the reliability of low-cost indoor PM2.5 measurements. The multi-stage calibration framework connects low-cost field sensors to be deployed with intermediate drift-correction reference sensors and a reference-grade instrument, applying separate calibration models for low (clean air environment) and high (pollution events) concentration ranges. We evaluated the framework in a controlled indoor chamber using two different sensor models exposed to diverse indoor pollution sources under uncontrolled natural ambient conditions. The AutoML-driven calibration significantly improved sensor performance, achieving a strong correlation with reference measurements (R2>0.90) and substantially reducing error metrics (with root-mean-square error (RMSE) and mean absolute error (MAE) roughly halved relative to uncalibrated data). Bias was effectively minimised, yielding calibrated readings closely aligned with the reference instrument. These findings demonstrate that our calibration strategy can convert low-cost sensors into a more reliable tool for indoor air pollution monitoring. The improved data quality supports atmospheric science research by enabling more accurate indoor PM2.5 monitoring, and informs public health interventions and evaluation by facilitating better indoor exposure assessment.

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Jadhav, A. M., Jadhav, O., Ranpise, P.

Enhancing Indoor Cooling Prediction Using Empirical Models Incorporating Occupancy and Humidity.

New Horizons of Science, Technology and Culture Vol. 4, Vol., (2025), 154-177 p.

The study presents an empirical approach to model the cooling behaviour of a controlled room under varying conditions of air conditioner (AC) setpoint, occupancy, and humidity.

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Xu, Z., Lu, W., Peng, Z.

Enhancing natural ventilation in modular buildings: A reversible WindModule graph generative design approach.

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

Modular construction has gained prominence for its efficiency, sustainability, and rapid deployment. While research has focused on manufacturing, assembly, and functional design, the modularity principle often restricts the optimization of natural ventilation—a key factor for indoor air quality, humidity control, and thermal comfort. This study introduces a performance-based generative design method to optimize space layouts in modular construction and improve indoor ventilation. The proposed approach employs a WindModule graph framework to represent spatial combinations in floor plans, followed by computational fluid dynamics (CFD) simulations to assess ventilation rates. A heterogeneous graph attention network accelerates CFD-based predictions, and the Non-dominated Sorting Genetic Algorithm II generates a Pareto frontier of layouts that balance ventilation performance and cost. The framework was validated on a modular project in Hong Kong, which is a compact modularized student residential building. The optimized layouts achieved a 3.14 % improvement in natural ventilation and a 6.25 % cost reduction compared to the baseline. Analysis of multiple optimized layouts provided further insights, resulting in modular building designs with enhanced ventilation efficiency. This research presents an innovative framework for performance-driven generative design, supporting sustainable design strategies and the optimization of modular buildings.

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Bugarski, A. D., Ritter, D. A., Moredock, J. L.

Environmental Enclosure as a Control Technology for Reducing Exposure of Mobile Underground Mining Equipment Operators to Diesel Aerosols and Gases.

Mining, Metallurgy & Exploration, (2025)

This study was conducted to evaluate the potential role of the environmental enclosure with an air cleaning system as a technology for controlling operators' exposures to aerosols and criteria gases emitted by diesel-powered mobile equipment in underground environments. This laboratory evaluation was conducted using a testing facility custom designed to allow for evaluation of the environmental enclosures and associated Heating, ventilation, and air conditioning systems while being immersed in the diluted diesel exhaust. Four different configurations of the Heating, ventilation, and air conditioning system for the commercially available environmental enclosure of the underground mining load-haul-dump vehicle were evaluated at the custom-built test facility. The configurations were evaluated while immersed in the diluted diesel exhaust with a concentration of aerosols and criteria gases comparable to those in underground mines. The configurations fitted with high efficiency filter elements were found to provide more than 95 percent reductions in the number concentrations of diesel aerosols. The configurations with elements containing adsorbent reduced the NO_2 concentrations present outside of the enclosure in excess of the current personal exposure standards by more than 85 percent and increased NO concentrations by as much as 37 percent. None of the evaluated configurations had a substantial effect on the CO_2 concentrations present outside of the environmental enclosure system at concentrations equivalent to the current personal exposure standards for underground miners. The results suggest that air quality control systems could be optimized to allow for better control of the flow rates, pressurization of the enclosure, and influx of contaminants at the low-pressure zone of the systems. The control of CO_2 and NO exposures would continue to rest on supplying an adequate quantity and quality of fresh air to dilute those gases below targeted exposure standards.

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Kumar, S., Acharyya, S., Mukherji, S., Mukherji, S.

Ethanol Detection using Deprotonated Polypyrrole Coated Filter Paper Sensor.

2025 IEEE Sensors Applications Symposium (SAS)

Volatile organic compounds (VOCs) have become a concern in indoor environments due to their adverse health risks when exposed for a longer duration. Exposure to ethanol occurs through ingestion, human breath, building materials, and human activities. GC-MS based techniques are limited to laboratory

environments. Though metal oxide semiconductor (MOS) sensors resulted in miniaturization but require high operating temperatures. In this work, we report a room temperature operated deprotonated polypyrrole conducting polymer based chemiresistive sensor. At 1000 ppm, the response of 5% is achieved. The sensor allowed a detection limit of up to 100 ppm. Response with good reproducibility and repeatability was achieved. The results demonstrate the potential of conducting polymer sensors in ethanol detection in an indoor environment at room temperature.

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Correa, L.

Evaluación del comportamiento de sensores CO2 comerciales de bajo costo.

Pädi Boletín Científico de Ciencias Básicas e Ingenierías del ICBI, Vol. **13** n°(26), (2025)

El presente artículo describe la implementación un sistema de monitoreo de CO2 de una oficina de trabajo utilizando dispositivos IoT para la adquisición de señales , procesamiento de los valores y su transmisión en un modelo de cliente-servidor por medio de una red local inalámbrica “Wifi”, en la cual a cada sensor se le asigna un identificador de acuerdo a la zona donde fue colocado, se describen los equipos, el código de comunicación y el desarrollo de una interface web para la visualización de los valores medidos , además de la implementación de una base de datos para el almacenamiento e histórico de los valores monitoreados y puedan ser de utilidad para un posterior análisis del comportamiento de CO2.

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Ghorbani, V., Ghorbani, A., Yoo, C.

Evaluating deep learning data imputation for subway indoor air quality: Accuracy, efficiency, and implications for downstream tasks.

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

Missing data is a pervasive issue in environmental and building systems and poses significant challenges for indoor air quality (IAQ) management in subway stations, where sensor readings directly guide ventilation control, exposure assessment, and risk modeling. This paper evaluates a range of imputation techniques for subway IAQ time-series, comparing their reconstruction accuracy, computational efficiency, and impact on downstream tasks. Twelve models are assessed across twelve distinct missing data scenarios that vary in pattern and severity. The methods include nine advanced deep learning approaches covering sequence and attention models, probabilistic generative frameworks, graph aware techniques and spectral or convolutional architectures and three naive statistical methods. Experiments use a newly collected dataset from Yeongtong station in the Seoul metro system giving real data insights into IAQ imputation challenges. To our knowledge this is the first comprehensive evaluation linking algorithmic performance to both ventilation control implications and forecasting outcomes in a multi-zone IAQ monitoring context. This study demonstrates the importance of aligning imputation strategies with specific missingness characteristics and forecasting requirements by means of reconstruction accuracy, which improved downstream IAQ task performances of forecasting and ventilation control.

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Frumen, Ž.

Experimental analysis of the efficiency of standard F9 filters and the development of an improved prototype for advanced filtration systems. (en slovène).

Univerza v Ljubljani, Fakulteta za strojništvo. Thèse 2025

The presence of fine airborne particles, particularly PM1, significantly affects indoor air quality. Due to their small size, these particles can penetrate deep into the respiratory system and thus pose a health risk. In modern ventilation and air-conditioning (HVAC) systems, the use of efficient filtration solutions is therefore essential. These filters not only retain harmful particles but also maintain a low pressure drop, thereby

improving the overall energy efficiency of the HVAC system. This master's thesis analyses the performance of F9 class air filters in terms of PM1 particle retention, pressure drop, and energy efficiency. The experimental part involved a comparison of filters from three different manufacturers, with a focus on identifying the most favourable balance between filtration efficiency and airflow resistance caused by the filter. Measurements were conducted on a custom-designed test bench at various volumetric airflow rates, where filtration efficiency and pressure drop were recorded. Based on the analysis, the filter with the most favourable characteristics was selected as the basis for the development of an improved prototype. In the continuation of the research, various combinations of filtration materials and active surface areas were tested. The results demonstrated that optimizing the filter's construction can achieve high filtration efficiency while reducing pressure drop, which positively affects the energy balance and service life of the filter.

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Sallan, S., Kwong, Q. J., Leh Ling, O. H., Abdul Mutalib, A. F.

Exploring the correlation between building physical condition, indoor environmental quality and occupants' perception: a narrative review.

Facilities, (2025)

This paper aims to examine the relationship between the building physical condition (BPC) and indoor environmental quality (IEQ). Various building defects and their effects on occupants' comfort, satisfaction, health and productivity were identified and analysed.The six-phase thematic analysis was used to examine the content of 27 papers, and three primary themes were identified: BPC–IEQ Performance Assessment: Tools and Techniques, BPC's Influence on IEQ and Occupants' Effect: BPC–IEQ Relationship. The first theme emphasised innovative approaches for assessing criticality (defect, space and key performance indicator-based assessments). The second theme highlighted the significant correlation between BPC and IEQ, including the impact of building defects and external factors on indoor air quality. The third theme explored how BPC and IEQ settings influenced occupants' perceptions (satisfaction, health, comfort and absenteeism).An increasing interest about the correlation between BPC and IEQ was identified in this paper. Various issues, including cracks, insufficient insulation and inadequate ventilation systems, adversely impacted IEQ and occupants' perceptions. Research areas that require further investigation were also determined.The outcomes of this narrative review suggest the importance of BPC assessment in enabling facility managers to implement preventive maintenance, optimise building performance and make informed, data-driven decisions to enhance IEQ and occupant well-being.This paper contributes information regarding the correlation between BPC–IEQ, constraint identifications and potential research routes for improving building performance and the well-being of occupants, given that previous studies did not specifically explore these concerns.

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Zhao, W., Quan, W., Duan, X., Yan, R., Cui, W., Yu, T.*, et al.*

High sensitivity Ru-modified SnO2/SnS2 nanoflowers for rapid detection of H2S gas.

Chemical Engineering Journal, Vol. **522**, (2025)

SnS2 material has attracted much attention in gas-sensing applications owing to its suitable band gap width. However, SnS2-based gas sensors have disadvantages including unsatisfactory selectivity and slow response and recovery speed caused by the low conductivity. Here, the SnO2 nanospheres were in-situ grown onto the surface of SnS2 nanoflowers by the two-step solvothermal route to achieve rapidly detect H2S gas. Subsequently, noble metal Ru was employed to modify the optimized SnO2/SnS2(1:10) heterostructure. Gas-sensitive results show that the Ru-SnO2/SnS2(1:10) displays superior repeatability and selectivity to H2S at 200 °C. Furthermore, the Ru-SnO2/SnS2(1:10) sensor possesses an ultra-short response/recovery time of 3.9/41 s, as well as a large gas response of 9.89 for 100 ppm H2S. First-principles calculations confirmed the enhanced responsiveness of Ru-SnO2/SnS2 to H2S compared to pristine SnS2 and SnO2/SnS2 heterostructure materials. The enhanced sensing performance is mainly

ascribed to the substantial adsorption sites in the Ru-SnO2/SnS2 composite, the outstanding carrier migration capability due to the role of SnO2/SnS2 heterostructure, the robust gas adsorption ability caused by the Ru doping, and the varied hole accumulation layer induced by the Schottky barrier. This work offers a promising strategy to enhance the sensitive capability of H2S gas sensors.

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Nachtnebel, M., Fitzek, H. M., Mitsche, S., Egger, N., Fötsch, M., Steiner, M., *et al.*

Impact of clay construction components on indoor aerosols: what can automated SEM-EDX and Raman reveal?

17th Multinational Congress on Microscopy, MCM 2025. 8-12/09/25. Portorož, Slovénie

The construction of buildings is responsible for about 10% of the total greenhouse gas emissions worldwide [1]. The majority of this is generated in the production of building materials, like cement-, steel- and glass manufacturing. Substituting one of the materials with a natural source, thus will lead to a reduction of the environmental impact of this sector. In the “RE-FORM earth” project, various solutions are being developed for the integration of clay in the construction industry [2]. This is because this traditionally used material has not yet been standardised for modern construction work. One of the project subtasks is to analyse the impact of clay construction components on the indoor air quality, especially in terms of their contribution to dust particles.

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Akhtar, N., Tahir, A., Gulzar, Z., Qadir, A., Ahmed, B., Nasim, I.

Indoor air quality in healthcare: Evaluating the risks of nitrogen and sulfur oxides in dental practices.

Atmospheric Environment, Vol. **362**, (2025)

Objective This study aimed to assess indoor NO2 and SO2 levels in selected clinical and hospital dental units, identify sources linked to dental activities, and evaluate site and health risks from these gaseous oxides for students, professionals and patients, including immunocompromised. Method Ten different hospitals and clinical dental units were selected for this assessment. Key findings Annual average of 14.5 ± 4.6 μg/m3 of NO2 and 8.0 ± 1.7 μg/m3 of SO2 were recorded. A significant difference (<0.05) in NO2 and SO2 levels was found, while non-significant differences (>0.05) were observed between hospital and clinical units. Winter was more polluted due to higher gas levels, while spring was cleaner. Dunn's test showed a significant seasonal trend. Regression analysis revealed a robust (R2 = 0.9) to moderately strong (R2 = 0.6) correlation between the concentration of NO2 and SO2 except during winter (R2 = 0.4). The highest levels of nitrogen oxides were found during anesthesia performance, and higher sulfur oxides were observed during dental implantation and impression performance. Negligible site risk was found except during winter. Indvisual HQ-SO2 and HQ-NO2 did not present significant health risks to dentists except for HQ-NO2 to immunocompromised adult patients. Synergistic ΣHQ posed a significant HQ risk to immunocompromised patients at most dental units, but to adults at a few clinical sites. Conclusion Indoor and outdoor sources of pollutants should be closely monitored and controlled for patient safety and long-term exposure to dentists. Improve winter ventilation and use of high-evacuation system during high-exposure procedures, ensuring temperature and relative humidity are controlled.

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Kolluru, S. S. R., Purkayastha, S. D., Barudgar, A., Ojha, A., Pawar, P., Kumar, R.

Indoor air quality in Mumbai metropolitan region: spatio-temporal analysis of PM concentrations in diverse indoor environments in India.

Air Quality, Atmosphere & Health, (2025)

This study represents the extensive investigation of particulate matter (PM) concentrations in indoor environments in India, analyzing PM10, PM2.5, and PM1 levels across 109 locations in the Mumbai Metropolitan Region (MMR), India. The monitored locations included residences, offices, restaurants, shopping malls, and cinema theatres, providing comprehensive insights into spatial and temporal variations. Results indicate that indoor PM levels frequently exceed WHO and NAAQS guidelines, with the highest concentrations observed in restaurants and residences. Restaurants recorded the highest mean PM10 (94.2 ± 45.1 µg m-3) and PM2.5 (38.3 ± 25.7 µg m-3) primarily due to cooking emissions and inadequate ventilation. Residences followed, with mean PM10 and PM2.5 levels of 83.6 ± 39.3 µg m-3 and 30.7 ± 17.8 µg m-3, respectively. Homes near industrial zones had significantly elevated PM10 levels (116.2 ± 59.0 µg m-3) highlighting the impact of external pollution infiltration. In contrast, private offices and shopping malls with well-maintained HVAC systems exhibited lower PM10 concentrations (65.8 ± 40.0 µg m-3 and 72.1 ± 31.2 µg m-3, respectively). Temporal analysis revealed that peak-hour PM10 concentrations in cinema halls (105.1 ± 52.9 µg m-3) were nearly 1.7 times higher than during non-peak hours (63.8 ± 23.1 µg m-3), largely due to foot traffic and dust resuspension. The findings underscore the urgent need for IAQ regulations, enhanced ventilation strategies, and stricter emission controls to mitigate health risks. This research provides crucial data for policymakers and urban planners, facilitating evidence-based interventions to improve indoor air quality and safeguard public health.

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Abdul Halim, M. H., Ismail, A., Md Saki, S. R.

Indoor Air Quality Measurement Onboard Royal Malaysian Navy Warship: Implication for Crew Stress Level.

International Journal of Research and Innovation in Social Science, Vol. **IX** n°(VIII), (2025), 3461-3475 p.

Indoor Air Quality (IAQ) is a critical determinant of health, operational performance, and psychological well-being, particularly in enclosed and high-risk maritime environments such as warships. This study examines IAQ conditions onboard KD JEBAT, a Royal Malaysian Navy frigate, and their implications for crew stress levels. Five IAQ parameters, carbon dioxide (CO_2), carbon monoxide (CO), relative humidity, temperature, and air movement were systematically monitored using a calibrated IAQ multifunction data logger across four mission-critical compartments: the Galley, Combat Information Center (CIC), Bridge, and Machinery Control System Room (MCSR). Data were collected over an 8-hour surrogate duration, segmented into four operational time slots, and benchmarked against the Industry Code of Practice on Indoor Air Quality (ICOP 2010). Measurements were further contextualized against crew occupancy patterns, task intensity, and compartment functions. Finding of IAQ assessments revealed CO_2 exceedances in CIC and MCSR, low wind speeds in all compartments, and thermal discomfort across sections highlighting stress related conditions to ventilation and temperature imbalances. These environmental stressors were closely associated with cognitive fatigue, physiological strain, and reduced situational awareness.

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Awolesi, O., Ghafari, F., Reams, M.

Indoor Environmental Quality Assessment in the Built Environment: A Critical Synthesis of Methodologies and Energy Integration Practices.

Energy and Built Environment, (2025)

This study systematically reviews 99 research articles published over the past seven years, sourced from four reputable databases, to examine how indoor environmental quality (IEQ) is assessed and how energy data are integrated across various building types and climate zones. Five key IEQ assessment approaches emerged: subjective, objective, dual-method, weighting scheme, and computational model-aided methods. Although 41.4% of the articles included energy usage data, variations in monitoring duration, normalization techniques, and statistical rigor limited the ability to compare findings across studies. Tools like machine learning and IoT-enabled BIM show strong potential for real-time optimization of IEQ and energy performance, yet they remain underused. Thermal and lighting conditions were identified as the most

energy-intensive IEQ dimensions, though results often varied due to climatic and methodological differences. In several cases, energy-saving interventions inadvertently compromised indoor air quality and thermal comfort, highlighting the need for integrated, precautionary strategies. Surprisingly, only 7.1% of articles involved post-assessment stakeholder engagement or follow-up interventions, exposing a gap between research and real-world impact. This study highlights the importance of critically evaluating performance metrics for contextual relevance and methodological soundness. To advance both occupant well-being and building energy performance globally, the field must embrace standardized assessment models, climate-responsive design, and well-rounded post-intervention evaluations.

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Zhang, M., Li, Y., Zhang, X., Hu, J., Lv, L., An, N.*, et al.*

Indoor Exposure to Volatile Organic Compounds (Benzene, Toluene, Xylene, and Formaldehyde) and Associated Health Risk in Hotels of Hunan, China.

Indoor Air, Vol. **2025** n°(1), (2025)

Background: Indoor air pollution caused by volatile organic compounds (VOCs) has garnered considerable attention, but its extent in hotel environments remains underexplored. This research was aimed at measuring the levels of VOCs (benzene, toluene, xylene, and formaldehyde) in hotels and evaluate their health risks using quantitative risk assessment methods, including lifetime carcinogenic risk (R) and noncarcinogenic hazard quotient (HQ). Method: Air samples were gathered from 79 hotels during the summer and winter of 2023. We analyzed the concentrations of four VOCs and conducted a descriptive analysis of the results. Spearman's rank correlation and principal component analysis were utilized for statistical evaluation. US EPA guidelines were used to calculate both carcinogenic and noncarcinogenic risks, with uncertainty quantified through Monte Carlo simulation (10,000 iterations) to derive probabilistic risk distributions. Results: Formaldehyde was the most abundant compound found in hotels (median: 17 μg/m3, range: ND–130 μg/m3), and compliance rate reached 99.15% (GB 37488-2019 limit: 0.10 mg/m3). Principal component analysis revealed that adsorption/desorption processes, seasonal behaviors, emission sources, and humidity are the primary drivers of VOC variability in the hotel environment. The median HQ for the four VOCs was 5.25 × 10−2, all below 1. The median sum lifetime cancer risk for total VOCs was 2.45 × 10−5, and formaldehyde dominated the combined cancer risk. Conclusion: Formaldehyde is a primary pollutant in hotel air, and prolonged exposure (8 h/day, 6 days/week, and an exposure duration of 30 years) can pose a carcinogenic risk to humans. Improving ventilation and installing air purification systems are recommended to mitigate VOC exposures in the environments. However, this study has certain regional limitations in terms of geographical coverage, which may affect the generalizability of the findings.

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Cheng, Z., Lei, N., Xiong, J.

Investigating the early-stage emissions of formaldehyde/VOCs from building materials and their influencing factors.

Environmental Technology, (2025), 1-16 p.

As urbanization accelerates, the issue of pollutant discharge from building materials has become the focus of public attention. Conducted in a ventilated environmental chamber, the experiments investigated the emission characteristics of VOCs from dry and wet building materials, focusing on the influencing factors, such as temperature, relative humidity (RH), ventilation, and seasonality. The impact of influencing factors was quantified using a one-factor-at-a-time control method. This study establishes that environmental factors ? temperature, RH, air exchange rate (AER), and seasonality ? significantly influence VOC emissions from building materials. Elevated temperature and humidity consistently increase emission rates and concentrations, while higher AER reduces indoor VOC levels. Emissions peak rapidly upon material installation, decline sharply, and stabilize within predictable ranges. Seasonal variations show summer (high temperature/RH) yielding maximum emissions, contrasting with winter minima. Dry and wet materials

exhibit similar emission trends, though temperature exerts a stronger effect on formaldehyde release from dry materials, while RH elevates peak and stable concentrations for wet materials. AER demonstrates dual effects: promoting initial emissions while diluting concentrations long-term, warranting further investigation. The C-history method efficiently determines initial emittable concentrations, and validated predictive models accurately forecast steady-state emissions across varying conditions. These models reliably estimate long-term pollutant levels using short-term data, proving valuable for indoor air quality assessment, material selection, and ventilation design. The study provides valuable insights into the practical significance of temperature, RH, ventilation, and seasonality on the emission rates of formaldehyde and TVOC from building materials.

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Kanimozhi J.K; Logesh T; Prakash N; A. Yoganathan; Kandasamy C.A; E.Loganathan

IoT-Enabled Air Purifiers with Real-Time Quality Monitoring.

5th International Conference on Soft Computing for Security Applications (ICSCSA). 4-6 Aug. 2025, TamilNadu, India.

The aim of the research is to develop an Internet of Things (IoT)-based air purifier that uses Convolutional Neural Networks (CNN) to detect air quality in real-time. It will then compare the performance of the devices using Support Vector Machines (SVM) based on energy efficiency and air quality improvement. Materials and Methods: There are two groups utilized in this research work: Group 1 utilizes 26 instances of SVM to simulate IoT-based air cleaners, and Group 2 uses 26 examples of CNN for simulating IoT-based air cleaners. PM2.5, PM10, CO2, temperature, and relative humidity were read through IoT environmental sensors, whose readings were made available. The training and tests were conducted in Python TensorFlow, Scikit-Learn, and monitoring in real-time was conducted on Google Firebase and AWS IoT Core. 95% is the confidence level, 80% is the G Power value, and 0.05% is the threshold. Results: The CNN-based air purifier achieved 92.4% accuracy, greatly outperforming SVM at an accuracy of 85.7%. Despite the CNN-based model detecting pollutants 24% faster than SVM, energy consumption was decreased by 18%. With p=0.0056 statistical significance, the greatest reduction in air pollution was seen when PM2.5 was decreased by 65%. Conclusion: In contrast to SVM-based models, it has been shown that air purifiers backed by IoT using CNN tremendously enhance energy efficiency as well as the observation of air purity, thus being suitable for environmental surveillance and control against pollution.

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Zimmerman, J. H., Schumacher, B., Lutes, C. C., Cosky, B., Hayes, H.

Long-Term Performance of Passive Volatile Organic Compounds (VOCs) Samplers for Indoor Air.

Environments, Vol. **12** n°(8), (2025)

The reliability of passive samplers in measuring volatile organic compounds (VOCs) in indoor air depends on whether the uptake rate is constant given the environmental conditions and sampler exposure duration. The first phase of this study evaluated the performance of charcoal-based, solvent-extracted passive samplers (e.g., Radiello® 130 passive samplers with white diffusive bodies) over exposure periods ranging from 1 week to 1 year in a test house with known vapor intrusion (VI). Chloroform %Bias values exceeded the ±30% acceptance criterion after 4 weeks exposure. Benzene, hexane, and trichloroethylene (TCE) concentrations were within the acceptance criterion for up to three months. Toluene and tetrachloroethylene (PCE), the two least volatile compounds, demonstrated uniform uptake rates over one year. In the second phase of this study, testing of the longer exposure times of 6 months and 1 year were evaluated with three additional passive samplers: Waterloo Membrane SamplerTM (WMSTM), SKC 575 with secondary diffusive cover, and Radiello® 130 passive samplers with yellow diffusive bodies. The SKC 575 and Radiello® 130 passive samplers produced acceptable results (%Bias ≤ 30%) over the 6-month exposure period, while the WMSTM sampler results favored petroleum hydrocarbon more than chlorinated solvent uptake. After the 1-year exposure period, the passive sampler performances were acceptable

under specific conditions of this study. The results suggest that all three samplers can produce acceptable results over exposure time periods beyond 30 days and up to a year for some compounds.

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Shukla, S., Singh, D., Maurya, A., Manocha, C., Sharma, S., Kumar, V.*, et al.*

Machine learning-driven strategies for optimal design of heating, ventilation, and air-conditioning (HVAC) filter media.

Separation and Purification Technology, Vol. **380**, (2026)

The COVID-19 pandemic has highlighted the critical need to improve indoor air quality (IAQ) through efficient air filtration, especially in heating, ventilation, and air-conditioning (HVAC) systems. While dedicated high-performance filters are effective, their high-pressure drops result in significant energy consumption when used in HVAC systems. Herein, we report the application of machine learning (ML) models to predict filtration efficiency and pressure drop, enabling the design and optimisation of filter media in HVAC. Specifically, three ML models, Gaussian process regression (GPR), artificial neural network (ANN), and decision tree (DT), have been trained on a dataset obtained from the literature. The dataset comprised key structural parameters of a wide range of filter media. The GPR model emerged as the most reliable predictor, exhibiting the highest coefficient of determination (R2) and lowest root mean squared error (RMSE) in predicting filtration efficiency and pressure drop, rendering it the most reliable predictor for small and uncertain datasets. The robustness of the GPR model is further confirmed via validation with commercially available filter media. In addition, the ML models accurately capture the established relationship between filtration efficiency and its characteristic drop at the most penetrating particle size (MPPS).

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Zhang, S., Jiang, J., Zhang, X., Lin, Z.

Mechanism for advancing air distribution: Matching zonal priorities with cascade utilization of air potential.

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

Advancing air distribution is one of the core tasks for developing low-carbon and healthy building environments. However, the mechanism for advancing air distribution is unclear. This study reveals and justifies the mechanism for advancing air distribution, i.e., the air potential should be maximally used, which indicates the air potential is used cascadingly to match the zonal priorities. Regarding thermal comfort, the supply air should be used sequentially to condition the breathing, lower, and upper zones, which is described quantitatively by the Matching of Thermal Potential, a newly proposed index. The larger the Matching of Thermal Potential, the higher the energy efficiency. This is verified by the coefficient of determination (R2) of greater than 0.95 for the case studies on mixing ventilation, displacement ventilation, stratum ventilation, and interactive cascade ventilation. Moreover, due to the coupled heat and mass transfer, a higher Matching of Thermal Potential leads to a younger mean age of air in the breathing zone. According to the mechanism, a novel air distribution strategy, i.e., graded ventilation, is proposed as an example. It reduces energy consumption by 8.4% - 53.5% and the mean age of air in the breathing zone by 7.8% - 23.4% under different thermal conditions. The revealed mechanism contributes to advancing air distribution for improved energy efficiency and inhaled air quality while providing thermal comfort.

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Bhoonah, R., Roux, C., Schalbart, P., Peuportier, B.

A method for integrating indoor air quality into the life cycle assessment of buildings: application to the sizing of ventilation rates.

The International Journal of Life Cycle Assessment, (2025)

Life cycle assessment (LCA) is used for building ecodesign purposes, but ecodesign software rarely considers indoor air quality (IAQ). IAQ is critical to human health since we spend about 90% of our time indoors and are exposed to potentially hazardous substances. Its consideration in LCA foreground data could help make adequate design choices (e.g. materials, window layouts, or ventilation rates) and reduce buildings' impacts on human health while avoiding their transfer to other life cycle stages.

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Arslan, M., Munawar, S., Mahdjoubi, L., Manu, P.

Monitoring indoor environmental conditions in office buildings using a sustainable Agentic RAG-LLM system.

Energy and Buildings, Vol. **347**, (2025)

Indoor Environmental Conditions (IEC) play a crucial role in determining the health, productivity, and overall building performance of employees, as well as their energy consumption. Key parameters, such as temperature and humidity, are not only vital for thermal comfort but also offer opportunities to enhance energy efficiency when effectively monitored and managed. Accurate Thermal Comfort Monitoring (TCM) remains challenging to achieve because it requires the integration of diverse data sources and intelligent analysis, particularly in light of evolving global energy and sustainability standards. Although Building Information Modeling (BIM) is increasingly being adopted to manage complex building data, its integration with real-time sensor inputs remains vastly underutilized. Existing thermal monitoring systems are often development-intensive, require significant domain expertise, lack Natural Language (NL) interaction capabilities, and are not inherently adaptable, necessitating frequent technical upgrades. These limitations give rise to pressing concerns about long-term scalability, usability, and sustainability. To address these limitations, this study introduces ThermalComfortBot, an integrated Information System (IS) powered by Generative Artificial Intelligence (GenAI). ThermalComfortBot utilizes open-source technologies, including Large Language Models (LLMs) and Agentic Retrieval-Augmented Generation (RAG), to enhance thermal comfort and support energy optimization in buildings. The system integrates Building Information Modeling (BIM), sensor data, and external datasets to generate actionable insights, delivered through both textual explanations and graphical visualizations. This system utilizes flexible and adjustable LLMs that are guided by principles of sustainability, thereby making them cost-efficient, scalable, and practical for a diverse range of organizational environments. In a real-world case study, ThermalComfortBot outperforms traditional RAG-LLM, achieving 94% accuracy, 92% precision, and 89% recall, enhancing comfort and efficiency.

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Eid, A., Jodeh, S., Hanbali, G., Hawawreh, M., Chakir, A., Roth, E.

Multi-Output Machine-Learning Prediction of Volatile Organic Compounds (VOCs): Learning from Co-Emitted VOCs.

Environments, Vol. **12** n°(7), (2025)

Volatile Organic Compounds (VOCs) are important contributors to indoor and occupational air pollution, such as environments involving the extensive use of paints and solvents. The routine measurement of VOCs is often limited by resource constraints, creating a need for indirect estimation techniques. This work presents the need for a predictive framework that offers a practical, interpretable alternative to a full-spectrum chemical analysis and supports early exposure detection in resource-limited settings, contributing to environmental health monitoring and occupational risk assessment. This study explores the capability of machine learning to simultaneously predict the concentrations of five paint-related VOCs using other co-emitted VOCs along with demographic variables. Three models—Multi-Output Gaussian Process Regression (MOGP), CatBoost Multi-Output Regressor, and Multi-Output Neural Networks—were calibrated and each achieved a high predictive performance. Further, a feature importance analysis is conducted and showed that certain VOCs and some demographic variables consistently influenced the predictions across all models, pointing to common exposure determinants for individuals, regardless of their

specific exposure setting. Additionally, a subgroup analysis identified the exposure disparities across demographic groups, supporting targeted risk mitigation efforts.

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Dou, M., Wang, X., Li, Y., Song, J., Gong, A.

Occupational hazard exposures among archivists.

Frontiers in Public Health, Vol. **13**, (2025)

BackgroundArchival work environments, often characterized by inadequate ventilation and a high concentration of materials, are prone to the accumulation of diverse harmful substances. Continuous exposure to such an environment may result in an array of health problems.ObjectiveThis study strives to investigate and synthesize existing research on the occupational hazards encountered by archivists, classify these hazards, detail their associated health impacts, and proffer strategies to preserve and enhance the health of archivists.MethodsThis study followed the PRISMA guidelines to conduct a systematic search of multiple electronic databases, including Web of Science and PubMed, for articles on occupational hazards among archivists. Specific inclusion and exclusion criteria were applied to select relevant studies published between 2000 and 2025. The information organization followed a systematic approach conducted in four stages: question-posing, literature search, literature selection, data extraction and synthesis.ResultOur review reveals that archivists face multiple occupational hazards. Chemical hazards, including formaldehyde and toluene volatile organic compounds (VOCs), can cause respiratory problems, neurological damage. Biological hazards, such as mold and dust mites, can lead to allergic reactions and respiratory diseases. Physical hazards encompass inadequate temperature and humidity control, insufficient lighting, and ergonomic stress, resulting in eye strain and musculoskeletal injuries. Moreover, overwork and improper postures can cause chronic physical ailments.ConclusionThis review identifies that archivists are exposed to significant occupational hazards spanning chemical, biological, physical, and ergonomic dimensions, which contribute to a range of health issues. The findings underscore the necessity for in—depth research into archivists' occupational health and the urgent development of targeted protective strategies to address these hazards.

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Davern, M. J., Hu, Y., West, G. V., Kim, Y., Francini, M. H., Morrison, G. C.*, et al.*

Online Iodide Chemical Ionization Mass Spectrometry (I-CIMS) Enables Occupational Inhalation Exposure Assessment of 6:2 Fluorotelomer Alcohol (6:2 FTOH) Emitted to Air during Floor Waxing.

Environmental Science & Technology Letters, Vol. **12** n°(5), (2025), 607-612 p.

Fluorotelomer alcohols (FTOHs) are a class of per- and polyfluoroalkyl substances (PFAS) that have been reported in both indoor and outdoor air and are found in an array of consumer products, including waterproof textiles, fast food contact papers, and floor waxes. Time-integrated offline sampling methods for airborne FTOHs generally require sampling times of hours to weeks. Thus, integrated methods fail to capture the real-time dynamic behavior of sources, sinks, and exposure. Herein, we demonstrate the use of iodide chemical ionization mass spectrometry (I-CIMS) in capturing the real-time concentration dynamics of 6:2 FTOH in air during floor stripping and waxing in a university laboratory. Peak 6:2 FTOH concentrations during application of floor wax were 456.9, 406.3, and 263.2 ng m–3, respectively, for three layers of wax (60 s averages). Additionally, the average 6:2 FTOH emission factor per wax layer was 5.10 ± 0.17 μg m–2. We estimate a range of potential inhalation exposures from 1.6 to 460 ng kg–1, depending on ventilation and workplace practices. Some 6:2 FTOH is expected to biotransform to three terminal acids (perfluorohexanoic acid, perfluoroheptanoic acid, and 5:3 fluorotelomer carboxylic acid), increasing blood serum concentrations of perfluorocarboxylic acids by an estimated 0.01–3.8 ng mL–1 following application of three wax layers.

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Hasic Huskic, K., Yahya Agha, Y.

OVK-teknikers utmaningar samt förbättringsåtgärder.

This bachelor's thesis examines the main challenges faced by technicians involved in the mandatory ventilation inspection system in Sweden Obligatorisk Ventilationskontroll (OVK) and identifies improvement measures that can make the system more effective and fit for purpose. OVK is a legally mandated recurring inspection of ventilation systems in buildings, designed to ensure both healthy indoor air quality and energy-efficient operation. The study is set in the context of Sweden's and the EU's increasing demands for energy efficiency in the construction sector, where well-functioning ventilation is crucial for both energy performance and human health. The research questions guiding the study are:

What are the biggest challenges that OVK technicians face in their daily work?

Based on the challenges identified by OVK technicians, what practical and strategic improvement measures can be implemented to improve the OVK process?

The aim is to analyze weaknesses in the current control system from the technicians' perspective and propose improvements within the existing regulatory framework. The OVK system refers to the overarching structure of laws, regulations, and institutional responsibilities, while the OVK process refers to the practical execution of inspections in the field.

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Zhuang, Y., Anwar, A., Li, Z., Zhang, R., Shi, F., Lin, Y.*, et al.*

Particulate pollution in underground restaurants with increased use of prefabricated dishes: Characteristics and influential factors.

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

Particulate matter (PM) is a major air pollutant posing adverse health effect globally. The growing use of prefabricated dishes in China's underground restaurants raises concerns about particulate pollution. Limited natural ventilation and rapid cooking may contribute to higher particulate emissions, posing health risks to occupants and emphasizing the need for further investigation into pollution levels in these spaces. This study aims to address the research gap concerning particulate pollution from prefabricated dish preparation in real-world underground restaurants and to systematically examine the effects of potential influential factors. In this study, we monitored PM concentration over a year in 19 underground restaurants located in four types of underground space. The measured annual average PM1, PM2.5, and PM10 concentrations were 34.3 ± 16.3, 42.8 ± 16.7, and 78.6 ± 17.2 μg/m3, respectively, while the corresponding outdoor concentrations of PM2.5 and PM10 were 26.4 ± 17.6 and 48.2 ± 26.2 μg/m3. The average PM2.5 concentrations during business hour for employee exposure (47.3 ± 8.7 μg/m3) and during meal time customer exposure (48.0 ± 8.1 μg/m3) were over three times higher than the World Health Organization air quality guideline for 24-hour mean limit of 15 μg/m3. PM10 levels were nearly twice the recommended limit of 45 μg/m3, indicating a substantial health risk from exposure to cooking-related particulate pollution. Outdoor particle concentrations, time relative to peak hours, season, kitchen type, and business hours were identified as the most influential factors affecting indoor PM concentrations. These findings provide basis for personal-exposure assessments and controlling strategy design.

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Kim, S.-H., Cho, I.-G., Lee, J., Kwon, J.-H., Choi, S.-D.

Performance Evaluation of Passive Air Samplers for Monitoring Volatile Organic Compounds in Indoor Air.

Journal of Korean Society for Atmospheric Environment, Vol. **41** n°(4), (2025), 607-621 p.

Despite the widespread use of passive air samplers (PASs) for measuring indoor volatile organic compounds (VOCs), the performance of PASs has rarely been systematically compared or evaluated. In this study, VOC samples were collected using three types of PASs in a dormitory and an office to compare

VOC concentrations and evaluate PAS performance. In addition, an active air sampler (AAS) was employed to calibrate the PAS measurement results. The PASs were deployed over a two-week sampling period. Sampling rates for each PAS were determined using the concentrations of eight compounds detected by the AAS. These sampling rates were then used to correct the PAS-derived concentrations. Before correction, VOC concentrations measured by the PASs differed significantly between the dormitory and the office (RM-ANOVA test: $p<0.05$). However, after correction, no significant differences in VOC concentrations were observed between the two locations (RM-ANOVA test: $p>0.05$). In the dormitory, the indoor/outdoor (I/O) ratio exceeded 1 for one compound before correction and for four compounds after correction. In the office, the number of compounds with an I/O ratio greater than 1 increased from four to five after correction. The estimated carcinogenic risk in the dormitory increased from 2.0E-06 to 5.8E-06 before and after correction, respectively, while in the office, it rose from 2.7E-06 to 7.9E-06, both exceeding the US EPA threshold of 1.0E-06. Since I/O ratios and cancer risk estimates are sensitive to sampling rate corrections, it is crucial to evaluate the reliability of PAS sampling rates thoroughly.

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Qiao, M., Yang, Y., Zhu, N., Wang, Y., Li, S., Cao, Q.*, et al.*

A physics-informed neural network integrating physical mechanisms and experimental data for predicting VOCs emission rates in machining workshops.

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

In machining workshops, metalworking fluids (MWFs) are widely used in cutting, grinding, and milling operations, resulting in substantial emissions of volatile organic compounds (VOCs), which pose serious risks to both human health and the environment. However, due to the complexity of VOCs emission behavior in these scenarios, accurately predicting emission rates remains a major challenge. Accurate prediction of VOCs emission rates is a prerequisite for effectively controlling in machining workshops. In this study, the effects of various process and environmental parameters on VOCs emission rates during cutting were experimentally investigated, key influencing factors were identified, and an experimental dataset was established. Subsequently, by incorporating the improved Langmuir-Maxwell theory as a physical constraint and combining feature engineering, a physics-informed neural network VOCs emission rate model based on semi-empirical formula (VERF-PINN model) was developed to accurately predict VOCs emission rate. The results showed that VOCs emission rates are significantly affected by MWFs type, workpiece temperature, and ambient temperature. The VERF-PINN model demonstrated high predictive accuracy, achieving values of the coefficient of determination (R^2) of 0.991 and 0.975 for oil-based and water-based test sets, respectively, with the mean absolute percentage error (MAPE) below 5.0 %. The model outperformed the theoretical formula, the backpropagation (BP) neural network, and the physics-informed neural network (PINN) models. This study proposes a VOCs emission rate prediction method with theoretical and engineering value, supporting ventilation design and providing a reliable basis for indoor air quality control in machining workshops.

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Hassan, M. A., Liu, J., Mehmood, T., Pei, J., Lv, M.

Prioritizing odorous VOCs emitted from air filters using machine learning models.

Journal of Hazardous Materials, Vol. **497**, (2025)

Atmospheric ozone reacts with pollutants accumulated on air filters in mechanical ventilation systems, generating odorous volatile organic compounds (VOCs). As atmospheric pollutants evolve and ozone-driven reactions intensify, new compounds may form, exacerbating odor issues. This study aims to train a machine learning framework for predicting the odor thresholds of VOCs emitted from air filters. To achieve this, machine learning models (Random Forest, Bagging Regression and Gradient Boosting) were trained based on datasets comprising 874 VOCs and 240 properties of each VOC to efficiently predict odor thresholds. Two types of used air filters were selected for a case study, with emitted VOCs were analyzed using GC-MS and HPLC at different ozone levels. Results indicated that ozone substantially increased

VOC emissions from filters, with the number of detected VOC and total VOC concentrations rising by 1.1–1.6 times and 2.1–2.9 times, respectively. Random Forest model outperformed others with R2 = 0.786 and RMSE = 0.657. Using odor activity values, aldehydes were identified as primary odor contributors. This study identifies potential odorous VOCs on air filters, offering insights for targeted VOC monitoring and odor control.

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Sakai, S., Tokumura, M., Enomoto, T., Tatsu, K., Shinohara, N., Makino, M.

A quantitative non-targeted analysis framework for comprehensive risk screening of chemical substances in vehicle cabin air.

Next Research, Vol. **2** n°(4), (2025)

Air quality within vehicle cabins is an emerging public health concern. Traditional analytical methods, which rely on targeted approaches, fail to address the huge range of potentially hazardous substances. Here, we propose a novel framework that combines quantitative non-targeted analysis (qNTA) using thermal desorption-gas chromatography-mass spectrometry coupled with post-column reaction flame ionization detection and in silico toxicity predictions to provide a more holistic assessment in terms of human health risks. Notably, this method enables simultaneous qualitative and quantitative analysis. Qualitative molecular information, including chemical composition, was obtained through mass spectrometry. Simultaneously, the detected compounds were converted into methane using a catalytic post-column reactor, allowing flame ionization detection to determine their concentrations based on methane-equivalent carbon concentrations. To validate the potential of this framework, we applied it to analyze substances present in bus cabin air under two scenarios: ride mode and parked mode; a total of 205 chemical compounds were detected in ride mode and 191 in parked mode, of which 144 and 141 compounds, respectively, were successfully identified. While qNTA independently offers comprehensive concentration data, the strength of this framework is that it integrates in silico toxicity predictions, enabling the translation of chemical concentrations into risk-based metrics and thereby facilitating a more meaningful assessment in terms of human health risks.

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Guo, F., Ham, S. W., Kim, D.

Reinforcement Learning Control for Buildings Co-Optimizing Energy, Comfort, and Indoor Air Quality: An Annual Assessment.

2025 IEEE Conference on Control Technology and Applications (CCTA)

Efficient control of Heating, Ventilation, and Air Conditioning (HVAC) systems is crucial for optimizing energy use and maintaining indoor comfort in buildings. Traditional control methods, such as PID control, cannot handle energy use trade-offs among multiple components in the building energy system at a supervisory level. Reinforcement learning (RL) presents a promising solution, offering adaptive and data-driven control strategies that optimize performance over time. However, RL also faces several challenges, including the conflicts encountered in co-optimizing energy savings, occupant comfort, and indoor air quality, and the requirement for extensive interactions with the environment in training. We proposed a flexible simulation platform that integrates a hybrid model for RL training and designed an RL agent to control the entire central HVAC system, focusing on co-optimizing energy consumption, thermal comfort, and indoor air quality (CO2 and PM2.5 concentrations). Finally, we evaluated the RL agent's performance over an annual cycle. Our findings indicate that the RL agent can effectively manage the HVAC system with 14.7 % energy savings annually and balance multiple objectives, which demonstrates significant potential for improving HVAC system control and sustainability in buildings.

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Li, H., Appel-Meulenbroek, R., Arentze, T. A., Hoes, P.-J.

Revealing and modelling occupants' preferences for comfort adaptive actions in open-plan offices with the inclusion of contextual and social-psychological aspects.

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

Office occupants interact dynamically with indoor environment control systems to perform daily routines and to maintain, restore, or enhance their comfort and needs. Traditional surveys and lab studies have been used to identify occupants' attitudes, behaviours, and the role of demographic characteristics over time or in response to specific environmental conditions. However, there has been limited investigation into how occupants choose different building controls when experiencing multi-modal discomfort, or how social dynamics, e.g., the influence of colleagues, shape such adaptive actions. This study addresses this gap through a survey-based stated choice experiment. The design of the experiment included four types of influential factors: building characteristics, contextual factors, environmental factors, and personal factors. The results show that office employees' preferences for various comfort measures are highly situational and context dependent. Additionally, in open-plan office areas, employees tend to show cooperative intentions, often accepting others' proposals for adaptations and being less likely to seek additional measures. A resulting discrete choice model effectively captures individual preferences through a utility function, enabling detailed modelling of the choice behaviour. This method is also flexible for modelling multiple behaviours and social interactions among office employees.

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Destrieux, A., Jangra, R., Hensel, K., Machala, Z.

Review on scientific studies and commercial indoor air purification devices: Focus on plasma-catalytic technology.

Journal of Electrostatics, Vol. **137**, (2025)

According to World Health Organization, urban populations spend 90 % of their time in indoor environments. Accentuated by the recent COVID-19 pandemic, this raises important concerns about the quality of the indoor air, which often contains various types of contaminants within three main categories: biological, volatile organic compounds, and particulate matter. Several technologies already exist for removing contaminants from indoor air, such as electrostatic based methods or filtration. Although these technologies are well established, they often target only one or two groups of contaminants. This review focuses on a promising technology: nonthermal plasma combined with catalysts. After an overview of indoor air contaminants, their sources, and the typical methods used for their removal, a highlight is put on the available commercial indoor air purification devices. The latter are rarely described in literature, and the comparison with lab-scale experiments are difficult due to the lack of information and available data from the manufacturers. The limitations of those systems are also discussed. As most of these commercial devices use combinations of various conventional technologies, the last part focuses on the ongoing research on plasma-catalytic systems. The main mechanisms are presented along with recent literature. Finally, some perspectives for its future development are proposed.

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Fathi, S., Fakhraeimanesh, S.

Smart materials in building façades: A systematic review of applications and impacts on energy efficiency.

Energy Reports, Vol. **14**, (2025), 2123-2140 p.

Indoor environmental quality (IEQ) is associated with several factors, all of which are related to occupant comfort within buildings. One of the most critical components of the buildings is building façade, which serves as the boundary between the indoor and outdoor environment. This paper presents a systematic review to investigate the application of high-tech materials – also known as smart materials in both transparent and opaque elements of building facades. To achieve the objectives of this study, we developed a structured systematic review to identify the relevant studies. Using the inclusion and exclusion

criteria, 157 records were identified as relevant studies. These studies were then classified based on their focus on IEQ factors, including thermal comfort and indoor air quality (IAQ). In the next step, details of research methodologies used in the reviewed studies – such as the simulation software employed – were reported. Furthermore, the total number of studies that applied smart materials to different parts of the building façade was presented, distinguishing between passive and active technologies. Finally, the impacts of these materials on overall energy consumption, heating demand, and cooling demand were discussed. Among passive measures, low-emissivity (low-E) windows were identified as effective in reducing total energy use, heating load, and cooling load. For active measures, photovoltaic (PV) systems in both transparent and opaque façade elements, as along with electrochromic (EC) windows, were found to significantly reduce total energy consumption as well as heating and cooling demands.

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Thakuri, A., Banerjee, M., Chatterjee, A.

Solid-Phase Coassembly of Polydiacetylene and Azo Dye Exhibiting Green-to-Orange Transition for VOC Sensing.

ACS Applied Polymer Materials, (2025)

The distinctive blue-to-red chromatic transition of polydiacetylenes has been greatly employed for the generation of colorimetric sensors for many chemically and biologically important analytes. However, very few efforts have been dedicated to the development of color-tunable polydiacetylenes. Herein, we report the design and development of a polydiacetylene-based solid-phase sensor with a unique green-to-orange chromatic transition. The sensor was developed by comixing 10,12-pentacosadiynoic acid (PCDA) with aniline yellow, a commercial aromatic azo dye, and coating it on strips of filter paper. The coassembly of azo dye and PCDA offers a green color upon UV irradiation (254 nm), and it displays the expected colorimetric transition under temperature and pH change, indicating that PCDA retains all its chromatic properties in the solid phase. These PCDA:azo strips were capable of detecting a series of different classes of VOCs, such as chlorinated solvents, hydrocarbons, and ethers, by green-to-orange chromatic changes, indicating their high potential as a VOC sensor. The normalized intensity plot from ImageJ showed that the strips detected common VOCs in under 1 min, indicating a quick response. The PCDA:azo strips also displayed better stability and sensitivity than the PCDA strips. The PCDA:azo strips were also able to detect VOCs released in real samples, such as primers and rotten meat, signifying their real-world applicability.

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Madsen, A. M., Árnadóttir, H. B., Bertier, P., Tunney, M. M., Hannerz, H., Verpaele, S.*, et al.*

Species-resolved exposure to fungi and bacteria, dust, and endotoxin during recycling of diverse waste types and systemic inflammatory response in workers.

Ecotoxicology and Environmental Safety, Vol. **304**, (2025)

The waste recycling workforce is growing across Europe. This study investigates the airborne exposure of workers recycling plastic, paper/cardboard, and electronic (e) waste, and examines whether serum levels of inflammatory markers correlate with exposure. Exposure was measured repeatedly and analysed for inhalable and respirable dust, inhalable endotoxin, fungi, and bacteria. Microorganisms were identified using MALDI-TOF MS on cultured microorganisms and bacteria by 16S rRNA marker-gene sequencing. Blood samples collected at the end of each workday were analysed for three markers of inflammation. Waste types/tasks had an impact on exposure levels for all exposures and temperature on exposure to anaerobic bacteria. Exposure levels to dust, endotoxin, and anaerobic bacteria differed between workers. Exposures were highest for those handling paper/cardboard and plastic waste. The alpha diversity indices for most exposures did not differ between types of waste handled, but eWaste was associated with a lower species richness. Beta diversity did not differ between indoor temperatures or waste types except for mesophilic bacteria and bacteria (NGS-data). The species Aspergillus niger, Penicillium brevicompactum, Bacillus cereus, and Staphylococcus equorum were frequently detected. Serum levels of inflammatory

markers increased with increasing exposure to dust, fungi or Penicillium spp, and anaerobic bacteria, but did not correlate with bacterial biodiversity indices. The study suggests further investigations of the impact of daily inhalation of bacteria able to grow anaerobically and fungi. Based on the high exposure levels, and the association between exposure and biomarkers of inflammation, it is advisable to explore risk management strategies aimed at minimizing worker exposure.

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Amangeldy, B., Tasmurzayev, N., Imash, A., Kaidar, B., Abdissattar, A., Smagulova, G.

Temporal Analysis of Indoor Air Quality Parameters in Metro Systems: A Focus on Diurnal Changes.

In: Computer and Electrical Engineering. IOS Press; 2025. 124-134 p.

Air quality in public transportation systems, particularly in subway networks, has become an important factor in passenger health and well-being. The development of advanced monitoring technologies, such as IoT sensors, has enabled the real-time measurement of air quality parameters like CO2, PM2.5, and PM10, allowing for a better understanding of environmental conditions in enclosed spaces. However, the impact of varying passenger density on air quality throughout the day, especially during peak hours, has not been sufficiently studied. This study addresses this gap by comparing air quality measurements in subway stations during peak hours and quieter periods. Here, we show that air quality parameters, including CO2, PM2.5, and PM10, significantly worsen during peak hours due to the higher passenger density, which contrasts with prior assumptions that air quality remains relatively constant throughout the day. These findings expand our understanding of how crowded conditions affect air quality, highlighting the need for more effective air circulation and filtration systems during peak times. This research emphasizes the importance of incorporating real-time air quality monitoring into subway system management to improve health outcomes for passengers and workers. Ultimately, the integration of advanced sensor networks could lead to the development of more efficient, responsive systems for managing air quality in urban transit environments.

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Hernández-Oramas, M., Navarro-Ibarra, D. C., Franco-Luján, V. A., Román-Doval, R., Toledo-Toledo, F., Ojeda-López, R.*, et al.*

Transition-Metal Ni6−xCux (x = 0–6)/Hexagonal Boron Nitride Composite for CO Detection: A DFT Study.

Journal of Composites Science, Vol. **9** n°(9), (2025)

The development of highly selective and sensitive gas sensors is essential for detecting toxic pollutants, such as carbon monoxide (CO), which pose severe health and environmental risks. In this work, the adsorption of CO molecules on Ni6−xCux (x = 0–6) clusters supported on hexagonal boron nitride quantum dots with nitrogen vacancies (h-BNVQDs) is explored through density functional theory (DFT) calculations. For this purpose, the stability of the metallic clusters supported on the boron nitride sheet was calculated, and the adsorption properties of the CO molecule on the Ni6−xCux (x = 0–6)/h-BNVQDs composite were determined. The results demonstrated a high binding energy between Ni6−xCux (x = 0–6) clusters and the h-BNVQDs sheets, suggesting that Ni-Cu clusters are highly stable on h-BNVQDs sheets. For CO adsorption, adsorption energy and charge transfer calculations indicated that the Ni6 and Ni6−xCux (x = 2 and 3) clusters exhibit the strongest CO binding and highest charge transfer, suggesting them as good candidates for CO gas sensing. These findings provide theoretical insights into the rational design of bimetallic catalysts for gas-sensing applications.

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Natarajamani, G. S., Madanagursamy, S.

Unraveling recovery kinetics of a UV-activated chemiresistive NH3 gas sensor using g-C_3N_4/ZnO hybrid structure for ultra-selective low PPM detection at ambient temperature.

Journal of Environmental Chemical Engineering, Vol. **13** n°(5), (2025)

The advancement of next-generation NH3 gas sensors are confronted with the dual challenge of achieving both high sensitivity and operational stability at ambient temperatures. This study reports on a UV-activated (365 nm) g-C_3N_4/ZnO hybrid thin-film sensor designed for efficient NH3 detection at 300 K. ZnO thin films were fabricated using DC reactive sputtering, while g-C_3N_4 was synthesized through thermal polymerization. Structural and morphological characterizations confirmed successful hybridization, and Swanepoel analysis indicated an increase in film thickness upon the integration of g-C_3N_4. The layered g-C_3N_4 provided additional active sites, thereby enhancing NH3 adsorption. Under UV illumination, the hybrid sensor demonstrated a 16.6-fold improvement in sensitivity compared to pristine ZnO, with a response (Igas/Iair) of 17.3 at 10 ppm and a detection limit of 0.3 ppm. Langmuir adsorption analysis suggested that UV-induced charge separation significantly enhanced gas adsorption and carrier transport. The sensor exhibited a rapid response time (48 s), fast recovery (45 s), excellent long-term stability (60 days), and good humidity tolerance. UV activation also facilitated NH3 oxidation through reactive O2 species, enabling efficient and selective detection. The repeatability over three cycles confirmed the reliability of the sensor. These findings highlight the potential of g-C_3N_4/ZnO hybrid films for applications in indoor air quality monitoring, industrial safety systems, and intelligent sensing in smart agriculture.

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