Bulletin de veille QAI
N°06-2025 – 04/06/2025

Objectif : *Qualité de l'air intérieur*

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Google Scholar, Lens, WoS

Nelson, J., Bills, M.

AI-Driven Predictive Analytics for Optimizing HVAC System Performance in Commercial Facilities.

ResearchGate, (2025)

In commercial facilities, optimizing HVAC (Heating, Ventilation, and Air Conditioning) system performance is crucial for enhancing energy efficiency, ensuring occupant comfort, and maintaining indoor air quality. This study explores the application of AI-driven predictive analytics as a transformative approach to HVAC optimization. By leveraging data from IoT sensors, historical performance metrics, and external environmental factors, predictive analytics enables facility managers to anticipate maintenance needs, reduce energy consumption, and improve overall system performance. The chapter begins with an overview of HVAC systems and their common challenges, such as energy inefficiency and maintenance issues. It then defines predictive analytics and discusses its benefits for HVAC systems, highlighting how proactive maintenance and real-time decision-making can lead to significant operational improvements. The study delves into various AI techniques, including machine learning algorithms and data processing methods, that underpin effective predictive analytics. Implementation strategies for integrating AI-driven analytics into existing HVAC systems are outlined, supported by case studies that demonstrate successful applications in different commercial settings. The challenges and limitations associated with data quality, system integration, and organizational readiness are also examined, providing a comprehensive view of potential obstacles.

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Kalaivani, R., Sampoornam, K. P., Mathi, G. S., Nivetha, M.

AI–based IoT Real Time Air Monitoring System.

2025 5th International Conference on Trends in Material Science and Inventive Materials (ICTMIM)

In order to detect and forecast air pollutants, this study suggests a real-time air quality monitoring system based on AI and IoT. To offer precise and trustworthy air quality data, the system combines sensors, Internet of Things devices, and machine learning algorithms. With an accuracy rate of more than 90%, the suggested system can identify and predict air pollutants such as O3, PM2.5, and NO2. Stakeholders can access air quality data and get tailored suggestions using a mobile application and real-time data visualization dashboard. Proactive steps to lower air pollution are made possible by the system's predictive analytics capability, improving public health and environmental sustainability.

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Wang, Y., Gao, R., Tian, Y., Jing, R., Liu, M., Li, A.

An air balancing method for ventilation systems considering random fluctuations: Flow prediction and operating condition optimization.

Building and Environment, Vol. **281**, (2025)

This study develops an air balancing method combining Multi-task Gaussian Process Regression (MTGPR) and Genetic Algorithm (GA) to overcome two shortcomings in ventilation system control. Firstly, conventional methods rely on time-averaged velocity measurements for flow modeling, which neglect to account for the phenomenon of random fluctuations in airflow. Secondly, existing methods employ implicit flow prediction models, which can only predict the damper adjustment angles based on target flow rates, while failing to provide explicit branch flow predictions. The proposed MTGPR-GA method addresses these shortcomings through two core advancements: (1) an explicit flow prediction model that accurately

estimates time-averaged velocities based on instantaneous velocities from a single sample, and (2) GA-driven optimization of damper configurations and fan operations to achieve precise airflow balancing coupled with energy efficiency enhancement. To validate the effectiveness of the MTGPR-GA method, Computational Fluid Dynamics (CFD) simulation tests were conducted in both three-dimensional and two-dimensional ventilation systems. In the three-dimensional simulation, the average errors of the branch flow rates under four operating conditions were 4.04 %, 4.95 %, 2.64 %, and 3.78 %, with a fan pressure error of 5.01 %. In the two-dimensional simulation, under 30 sets of operating conditions, the average errors of the branch flow rates were 3.50 %, 4.45 %, 4.90 %, and 5.07 %, with a fan pressure error of 2.10 %. In all conditions, the damper of the most unfavorable loop remained fully open, ensuring that the fan operated with minimal energy consumption. The results demonstrate the effectiveness of the MTGPR-GA method in achieving air balancing and its energy-saving potential.

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Sullivan, P., Psomas, T., Devarapu, G. C. R., Donovan, A. C. O.

Assessing Suburban Air Quality Constraints on Free Cooling in an Irish City.

arXiv preprint arXiv:2505.04746, (2025)

Temperate climates are expected to have an expansion of the number of hours where ventilative cooling is needed and where potential is available even under climate change scenarios. Further to this, the use of free cooling in the form of untreated outdoor air has the potential to be a renewable energy source that adds flexibility to national electricity grids if used appropriately and is critical in decarbonising cooling more generally, particularly where coupled with significant thermal mass in buildings. The following study utilises external air quality measurements from the PASSESPARTOUT project and were collected from unique external air quality systems located in Cork in Ireland. The study characterises this data according to constraints based on control limits for cooling systems and for individual external air quality parameters. While the work aims to demonstrate the barriers to cooling potential that may exist due to poor external air quality, it also offers insights into where good urban air quality supports diurnal ventilative cooling strategies that are best suited given these limitations. The findings show that out of seven outdoor pollutants investigated, NO2 and PM2.5 were consistently above recommended threshold limits in suburban areas and present a barrier to the use of indoor-outdoor direct airflow coupling using natural ventilation strategies for ventilative cooling purposes. Indoor concentration levels within the surrounding areas to those investigated should be evaluated to develop Indoor-Outdoor ratios for designers for barrier pollutants.

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Vaicekonyte, R., Aristizabal, S., Obraztsova, A.

Building Well at Delos Office: Work/Life Elevated on Manhattan's West Side High Line.

In: Designing Healthy Buildings and Communities: Shaping a Climate-Resilient Future.

Springer Nature Singapore; 2025. 11-24 p.

This case study explores the design and construction of Delos Global Headquarters at 860 Washington Street in New York City, a cutting-edge example of integrating health, wellness, and sustainability in the built environment. The building, situated above the High Line, epitomises the intersection of modern architecture and progressive building certification standards, including WELL New & Existing Interiors, LEED v4, and Living Building Challenge Petal Certification. Delos HQ serves as a model for "Building-level Practices" by applying the 10 concepts of the WELL Building Standard™ (WELL)—Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind, and Community—each playing a part in a holistic strategy for occupant health and well-being. Methodologically, the case study examines the incorporation of advanced HVAC systems, underfloor air distribution, and MERV 13 filters to optimise air quality and thermal comfort among employees throughout the office space. It also evaluates the use of biophilic design elements, circadian lighting systems, and sound-absorbing materials to enhance both physical and mental comfort. The office layout promotes movement through features like open stairways and interactive digital screens, while ergonomic workstations and a variety of focus rooms cater to different

work styles. At a community level, Delos HQ strengthens its connection to the neighbourhood through its industrial design inspired by the High Line and a terrace that supports local biodiversity. In addition, the building demonstrates its commitment to sustainability through its recycling and composting practices, the use of energy-efficient appliances, and the incorporation of reclaimed wood. Collectively, these building and community-level interventions foster a holistic environment that promotes occupant health, productivity and sustainability, and through rigorous adherence to WELL requirements, exemplify how innovative design and operational practices can set new benchmarks in building excellence.

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Jahedi, F., Haghighi Fard, N. J., Khafaie, M. A., Hesam, S., Dehbandi, R., Kaydi, N.

Characterization of Airborne Microplastics and Exposure Assessment in the Mahshahr Special Economic Zone, Northern Persian Gulf.

Atmospheric Pollution Research, (2025)

Atmospheric microplastics (MPs), due to their diminutive size and potential health impacts, have become one of the biggest environmental and health challenges facing humanity. These particles can be easily inhaled, allowing them to bypass the body's initial respiratory defenses and enter the lung alveoli. Once lodged in the alveoli, these particles can cause various negative health effects, potentially leading to respiratory issues and other systemic health problems. This study marks the first quantification of atmospheric microplastics' spatial and temporal distribution in Bandar Mahshahr, Khuzestan, Iran. Measurements were conducted over twelve periods of 24-hour sampling across two months of the year at three different sites: residential, high-traffic, and industrial areas. The concentration of MPs in the indoor and outdoor air varied across the three sampling sites: it ranged from 0.16 to 1.11 particles/m3, with mean values of 0.47 ± 0.06, 0.78 ± 0.07, and 0.85 ± 0.09 particles/m3 for residential, high-traffic, and industrial areas, respectively. Industrial areas had the highest MP levels, followed by high-traffic and residential sites. Indoor air also contained significant MP concentrations. Regarding their color, and shape, the majority of MPs were identified as black-gray fibers (69.2–81.6%)with sizes mostly below 500 µm, though larger particles (>1000 µm) were also present. Moreover, Raman spectroscopic analysis revealed that the most prevalent types of plastics were polyethylene (PE), polystyrene (PS), polypropylene (PP), and nylon. The abundance of microplastics in present study can be attributed to the primary production of plastics by petrochemical industries located in the area. Our results can be attributed to the primary production of plastics by petrochemical industries located in the area. The inhalation risk assessment showed a significant disparity in MP inhalation exposure across different age groups, with newborns and infants facing the highest (0.44 MP/kg body weight/day, followed by infants at 0.23 MP/kg body weight/day, and adults at 0.07 MP/kg body weight/day). This study contributes to a better understanding of MP behavior in the atmosphere and emphasizes the need for further research to assess the potential health risks associated with MP exposure.

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Ranga, S., Warhade, V., Vishvanath Bhatt, J., Makwana, M., Rukadikar, C.

A Comparative Study of Pulmonary Function Test Results in AC Users Versus Non-Users.

International Journal of Innovative Science and Research Technology, Vol. **10** n°(4), (2025), 3065-3072 p.

Air conditioning (AC) has become a widespread necessity in modern environments, especially in urban and industrial areas. Despite its benefits in providing comfort, concerns are rising regarding the long-term effects of AC exposure on respiratory health. This study aims to compare pulmonary function test (PFT) results between individuals regularly exposed to air conditioning and those not exposed to it, to better understand the potential effects on lung function. Aim and Objectives: This paper was intended to evaluate the impact of air conditioning on lung function by comparing PFT outcomes of people who use air conditioning and those who do not. The first objective was to determine if respiratory health is affected after exposure to air conditioning. Methods: A cross-sectional comparative study was conducted for a period of 2.5 years. Two hundred participants from Kalol, Gandhinagar, Gujarat, 5 years of study. The participants

were categorized into two groups: AC users were defined as those people who had used air conditioning for more than six hours a day for at least one year while non-AC users were those who had no regular exposure to AC. Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Peak Expiratory Flow Rate (PEFR) and Forced Expiratory Flow 25-75% (FEF25-75%) pulmonary function tests were conducted using Portable Spirometer (Helios 702). The data was analyzed by unpaired t-test and chi-square test. ➢ Results: Results demonstrated significant reductions in lung function among AC users compared to non-AC users. Predicted FVC was significantly lower in AC users (2.31 ± 0.91 L) compared to non-AC users (3.37 ± 0.92 L, $p < 0.0001$). Similarly, predicted PEFR, FEF25-75% were significantly lower in AC users ($p = 0.04$ for both parameters). No significant differences were found in FEV1 or FEV1/FVC ratio among 2 groups ($p = 0.41$ and 0.89, respectively). The findings suggest that prolonged AC exposure can reduce lung volumes and affect small airway function. Conclusion: This study demonstrates that prolonged exposure to air conditioning may adversely affect lung volumes and airflow, particularly in the smaller airways. No significant differences were observed in FEV1 and FEV1/FVC ratio, the significant reductions in FVC, FEFR, and FEF25-75% highlight the potential respiratory risks associated with chronic AC exposure. Public health initiatives should emphasize proper AC maintenance and monitoring of lung function in individuals exposed to air conditioning for extended periods, particularly in occupational settings.

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Ahmad, F. B. J., Kek, H. Y., Tan, H., Fong, Y. K., Rahim, R. A., Wong, S. J.*, et al.*

Could Mobile Air Supply Unit Enhance Airflow Distribution in Office Environments?

Progress in Energy and Environment, Vol. **31** n°(1), (2025), 17-31 p.

Effective airflow management in office settings is crucial for good indoor air quality and occupant comfort. Poor air circulation can lead to health issues like increased respiratory infections and decreased productivity. This study examines the effectiveness of mobile air supply (MAS) units in enhancing airflow distribution within an office, comparing them with a primary air-conditioning system. A computational fluid dynamics (CFD) simulation using the Renormalization Group (RNG) k-ε turbulence model based on Reynolds-Averaged Navier-Stokes equations predicted airflow distribution. The model showed high accuracy, with an average relative error of 6.6%. The installation locations of MAS units did not significantly affect airflow around occupants. While MAS units can locally enhance airflow, their overall effect on office air distribution is minimal compared to the primary air-conditioning system. The highest velocities were up to 3 m/s near workstations, which diluted particulates but also raised thermal discomfort concerns. Units placed behind obstacles like furniture showed poor air mixing and ineffective distribution. The study highlights the importance of strategically positioning MAS units to optimize air distribution without compromising comfort. Future research should explore particle dispersion within these configurations and extend the use of mobile units to various building types, aiming to improve indoor air quality across different environments. Such research would support adaptive ventilation strategies that enhance air quality and energy efficiency, aligning with the United Nations Sustainable Development Goal (SDG) 3: Good Health and Well-being.

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Hamidreza Nabaei, S., Lenfant, R., Rajan, V. G., Chen, D., Timko, M. P., Campbell, B.*, et al.*

Detecting Plant VOC Traces Using Indoor Air Quality Sensors.

arXiv e-prints, (2025), arXiv:2504.03785

In the era of growing interest in healthy buildings and smart homes, the importance of sustainable, health conscious indoor environments is paramount. Smart tools, especially VOC sensors, are crucial for monitoring indoor air quality, yet interpreting signals from various VOC sources remains challenging. A promising approach involves understanding how indoor plants respond to environmental conditions. Plants produce terpenes, a type of VOC, when exposed to abiotic and biotic stressors - including pathogens, predators, light, and temperature - offering a novel pathway for monitoring indoor air quality. While prior work often relies on specialized laboratory sensors, our research leverages readily available commercial

sensors to detect and classify plant emitted VOCs that signify changes in indoor conditions. We quantified the sensitivity of these sensors by measuring 16 terpenes in controlled experiments, then identified and tested the most promising terpenes in realistic environments. We also examined physics based models to map VOC responses but found them lacking for real world complexity. Consequently, we trained machine learning models to classify terpenes using commercial sensors and identified optimal sensor placement. To validate this approach, we analyzed emissions from a living basil plant, successfully detecting terpene output. Our findings establish a foundation for overcoming challenges in plant VOC detection, paving the way for advanced plant based sensors to enhance indoor environmental quality in future smart buildings.

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Nie, T., Zhang, G., Sun, Y., Wang, W., Wang, T., Duan, H.

Effects of Indoor Air Quality on Human Physiological Impact: A Review.

Buildings, Vol. **15** n°(8), (2025)

As urbanization accelerates, indoor air quality has emerged as a critical determinant of population health. To systematically evaluate the relationship between indoor air quality (IAQ) and human physiological responses, we conducted a comprehensive review of 63 experimental studies retrieved from three major databases (ScienceDirect, Google Scholar, Web of Science) spanning the years 2000–2023. This systematic review synthesizes evidence from experimental studies examining the physiological impacts of indoor air contaminants, including gaseous pollutants, particulate matter (PM), and volatile organic compounds (VOCs). Through an analysis of cardiovascular biomarkers (heart rate variability, blood pressure), respiratory parameters, and neurological indicators (electroencephalogram patterns), we identify the mechanisms linking air quality degradation to impaired physiological functioning. Our findings demonstrate that optimized ventilation systems and high-efficiency particulate filtration can mitigate exposure risks, potentially enhancing cardiovascular efficiency, pulmonary capacity, and cognitive performance. The evidence further suggests that sustained improvements for indoor environments may decrease incidence rates of respiratory pathologies and neurological disorders.

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Gao, Y., Xue, Y., Sun, C., She, L., Peng, Y.

Emission Characteristics of Volatile Organic Compounds from Material Extrusion Printers Using Acrylonitrile–Butadiene–Styrene and Polylactic Acid Filaments in Printing Environments and Their Toxicological Concerns.

Toxics, Vol. **13** n°(4), (2025)

The utilization of 3D printing releases a multitude of harmful gas pollutants, posing potential health risks to operators. Materials extrusion (ME; also known as fused deposition modeling (FDM)), a widely adopted 3D printing technology, predominantly employs acrylonitrile–butadiene–styrene (ABS) and polylactic acid (PLA) as printing materials, with the respective market shares of these materials reaching approximately 75%. The extensive usage of ABS and PLA during the ME process leads to significant volatile organic compound (VOC) emissions, thereby deteriorating the quality of indoor air. Nevertheless, information regarding the emission characteristics of VOCs and their influencing factors, as well as the toxicological impacts of the printing processes, remains largely unknown. Herein, we thoroughly reviewed the emission characteristics of VOCs released during ME printing processes using ABS and PLA in various printing environments, such as chambers, laboratories, and workplaces, as well as their potential influencing factors under different environmental conditions. A total of 62 VOC substances were identified in chamber studies using ABS and PLA filaments; for example, styrene had an emission rate of 0.29–113.10 μg/min, and isopropyl alcohol had an emission rate of 3.55–56.53 μg/min. Emission rates vary depending on the composition of the filament's raw materials, additives (such as dyes and stabilizers), printing conditions (temperature), the printer's condition (whether it has closure), and other factors. Additionally, we reviewed the toxicological concerns associated with hazardous VOC species commonly detected during the ME printing process and estimated cancer and non-cancer risks for users after long-term inhalation exposure.

Potential health hazards associated with inhalation exposure to benzene, formaldehyde, acetaldehyde, styrene, and other substances were identified, which were calculated based on concentrations measured in real indoor environments. This study provides valuable insights for future research on the development of ME printing technologies and offers suggestions to reduce VOC emissions to protect users.

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Liang, Q., Bao, X., Qin, C., Zhang, Q., Zou, X., Xu, W.*, et al.*

Emissions of volatile organic compounds from COVID-19 response hospitals using mobile proton transfer reaction mass spectrometry observations in Wuhan in 2020.

International Journal of Mass Spectrometry, Vol. **514**, (2025)

To curb the rapid spread of the COVID-19, Wuhan was the first in the world to implement strict lockdown measures on January 23, 2020, and rapidly established several large hospitals. The extensive disinfection operations and daily activities within these hospitals led to the release of significant amounts of volatile organic compounds (VOCs). However, the composition and concentration characteristics of VOCs around these hospitals remain unclear. This study employed a self-developed mobile proton transfer reaction mass spectrometry (M-PTR-MS) system to conduct high spatiotemporal resolution mobile monitoring of VOCs in these hospitals in Wuhan from February 29 to March 15, 2020. The study compared the temporal and spatial variations in VOC across Wuhan, focusing on the frequency and concentration of VOC increases downwind of temporary hospital (Leishenshan Hospital), designated hospitals (Wuhan Xiehe Hospital, Wuhan Jinyintan Hospital), and shelter hospitals (Wuhan Keting Shelter Hospital, Hongshan Stadium Shelter Hospital). The results indicated that during the 14 days of effective mobile monitoring, the average concentration of total VOC (TVOC) in the first seven days was 13.39 % higher than in the latter seven days. Spatially, the average concentration of TVOC in the industrial areas north of the Yangtze River was 8.89 % higher than those in the non-industrial areas south of the river. Leishenshan Hospital exhibited the most diverse VOC composition and sources, with VOCs primarily originating from the fermentation and direct incineration of medical, waste within the hospital grounds and disinfectants. Downwind of the designated hospitals, VOCs related to industrial-source, disinfectants and waste were detected. Ethanol was detected downwind of all these hospitals. Waste generated by hospitals was a significant source of VOCs downwind of both temporary and designated hospitals. This study provides valuable technology for the research on VOC characteristics, disinfection efficacy evaluation, and environmental impact analysis during public health emergencies.

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Cebolla-Alemany, J., Macarulla Martí, M., Viana, M., Gasso-Domingo, S., Moreno-Martín, V., Bou, D.*, et al.*

Estimation of nanoparticle emissions in indoor industrial environments using a grey-box modeling approach.

Building and Environment, Vol. **281**, (2025)

Estimating nanoparticle emission rates from industrial activities is essential for developing quantitative risk assessment tools and prediction models for indoor air quality and occupational exposure. However, determining them is challenging, particularly for incidentally generated nanoparticles (INPs), due to their calculation from concentration measurements in complex environments with polluted backgrounds. This study addresses the challenges of defining INP emission rates by proposing a reduced-order grey-box modeling approach. The method was tested in three industrial scenarios with different thermal spraying activities, evaluating 78 models based on mass-balance aerosol concentration equations. Convergence tests, statistical analyses, and physical feasibility studies revealed that 33 % of the models met all criteria. The simplest models, incorporating forced ventilation and particle generation while excluding natural diffusion, aggregation, and deposition, demonstrated the best performance and robustness, with two models reaching a 100 % successful performance on six applied datasets. Emission rates for the monitored processes were of similar magnitude, with minor variations around 4 × 1015 particles/min attributed to the materials and component morphology. Estimated ventilation airflow rates also aligned with the expected

slight underperformance of the extraction systems between 1 and 22 × 107 cm3/min depending on the monitored booth and the ventilation configuration, showing air change per hour rates within the 39–105 h-1 range. The findings highlight that grey-box modeling combined with model reduction through lumped sum parameters provides a systematic and reliable approach to estimating INP emissions. This method could inform new standard procedures. Future research should apply this approach to diverse industrial activities and exposure applications.

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Seo, J. H., Kim, P.-G., Choi, Y.-H., Shin, W., Sochichiu, S., Khoshakhlagh, A. H.*, et al.*

Evaluation of personal exposure to volatile organic chemicals (VOCs) in small-scale dry-cleaning facilities using passive sampling.

Atmospheric Environment, Vol. **353**, (2025)

This study evaluates personal exposure to volatile organic compounds (VOCs) in 50 workers from small-scale dry-cleaning facilities using optimized ePTFE passive samplers, analyzing 13 VOCs. At mean exposure levels, significant non-carcinogenic risks were identified for trichloroethylene (TCE), while carcinogenic risks were confirmed for five compounds: styrene, benzene, ethylbenzene, dichloroethene (DCE), and perchloroethylene (PCE). Workers most frequently reported health changes (48 %), followed by specific symptoms such as dry skin (24 %), fatigue (22 %), skin irritation (20 %), and eye fatigue (20 %), all of which were associated with exposure to different VOCs in the workplace. These findings highlight the need for continuous monitoring and guidelines regarding working hours, particularly in small-scale workplaces. The VOC emissions from dry-cleaning facilities not only pose direct health risks to workers but also contribute to environmental pollution, highlighting the importance of proactive management and control measures in these businesses.

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Li, J., Chen, C., Zhang, T., Chen, K., Tao, J., Wang, K.

Evaluation of Vehicle Purification Capability Based on Typical Pollution Scenarios.

Polish Journal of Environmental Studies, (2025)

This study aims to develop a comprehensive, objective, and effective method for testing and evaluating the overall pollutant purification capability of vehicles, especially on practicality and reliability. Three performance indicators: the pollutant barrier of vehicles under static conditions, the purification of particulate pollutants, and the purification capacity of toxic and harmful gases, are mainly evaluated. Seven pollution scenarios and driving conditions, including static parking, sandstorms, cooking fumes, automotive exhaust, indoor smoking, industrial emissions, and hightemperature exposure, are established and assimilated. These scenarios were utilized to assess the purification capabilities of vehicles for particulate matter and toxic gases. Based on our method, seven vehicle models (each with different in-car purification configurations) were selected for testing. The results demonstrate that the numerical values of comprehensive pollutant purification capacity are related to the configuration levels of in-car purification devices, showing clear numerical differentiation. These values indicate the ability of vehicles to continuously, effectively, and reliably purify pollutants under typical pollution scenarios. Therefore, this comprehensive purification capability evaluation method provides a robust framework for assessing the pollutant purification capabilities of vehicles equipped with complex in-car purification systems.

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Riveron, T., Hansell, A., Cordell, R.

Evolution of volatile organic compounds and their health risks following the opening of a newly built office building.

Building and Environment, Vol. **280**, (2025)

Little is known about the time profile of volatile organic compound (VOC) concentrations in newly built office buildings. Several studies conducted in private buildings have shown high concentrations of VOCs are present during and shortly after construction, which then decrease over the next few months to reach lower and more stable concentrations. In this study, VOCs were sampled in four rooms of a newly built office building over the 15 months following its opening. The samples were analysed by comprehensive two-dimensional gas chromatography with dual flame ionisation detection and mass spectrometry. The study found high but fluctuating concentrations of VOCs, with a maximum TVOC concentration reaching 1492 µgm-3 in one office, one month after opening. After six months, the TVOC concentration reduced by 60 to 76 % and reached stable concentrations under 200 µgm-3 in all rooms. VOC concentrations and composition between rooms were impacted by the number of occupants and the position of the offices inside the building. To determine health impacts, hazard quotients (HQ) and cancer risks (CR) were calculated using the US Environmental Protection Agency (US EPA) reference values for inhalation exposures. At the end of the sampling period, all the HQs were under 1, suggesting that exposure to non-carcinogenic VOCs should not impact the health of the building's workers. CRs were between 1E-04 and 1E-06, which the US EPA identifies as providing possible risk from long-term exposure. More studies are needed to characterise VOC exposures and their potential risks to the occupants of newly built public buildings.

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Liang, W., Zhang, Y., Chong, A., Hameen, E. C., Loftness, V.

Exploring Gaussian Process Regression for indoor environmental quality: Spatiotemporal thermal and air quality modeling with mobile sensing.

Building and Environment, Vol. **281**, (2025)

Measuring and monitoring indoor environmental quality (IEQ) is essential to ensure occupants' health, well-being, and productivity in the built environment. Conventional IEQ assessment approaches, including stationary sensor networks and human-propelled field surveys, are limited in scalability in both spatial and temporal dimensions. To address this, researchers have developed mobile sensing platforms for more agile measuring and monitoring. However, a systematic modeling approach for reconstructing high-resolution spatiotemporal maps of IEQ variables from the sparse data collected by these mobile platforms is still lacking. This paper introduces a Gaussian Process Regression (GPR) framework designed to interpolate and process raw data from robotic mobile sensing platforms and IoT devices, thereby reconstructing spatiotemporal representations of various IEQ parameters from both short-term and long-term monitoring. The results demonstrate that for short-term spatiotemporal indoor air quality distribution reconstruction, GPR outperforms K-Nearest Neighbors (KNN), Random Forest (RF), and Support Vector Regression (SVR) when using different cross-validation strategies. In addition to a high correlation with the measurements and small normalized mean squared error, GPR models show a minimal bias in variance compared to the measured data. Secondly, when applied to long-term autoregressive modeling of an air temperature sensor network, GPR exhibits fast convergence and maintains a root-mean-square error of 0.21 °C over long-term predictions. The results suggest that GPR can capture the temporal and spatial variations in air temperature data. The two case studies demonstrate that the proposed approach holds the potential to serve as a robust and generalizable modeling framewoek to assist IEQ monitoring and assessments.

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Tamsi, N. S. F., Kamaruddin, A. F., Nik, K. I. K. A., Anuar, M. I., Ariffin, A., Zahaba, M.

Indoor Air Quality (IAQ) Mitigation Strategies for Marine Transportation: A Call for Ship IAQ Guidelines Development.

Journal of Ship and Marine Structures, Vol. **8** n°(1), (2025), 11-18 p.

Indoor air quality (IAQ) greatly influences human health, comfort, and life productivity. Ships with confined spaces and limited ventilation demand more attention for a good IAQ due to the accumulation of indoor air

pollutants (IAP) and the long time spent onboard. Nevertheless, studies have found ships recorded noncompliance with IAQ parameters to available standards, especially after shipbuilding and refurbishment programs. The lack of appropriate mitigation strategies to reduce the IAP onboard has contributed to this issue, as there are no available IAQ guidelines designed explicitly for ships. Hence, to highlight the importance of having ship IAQ guidelines, this study evaluated the effectiveness of building IAQ mitigation strategies practised in a ship after a refit program. The effectiveness was evaluated by conducting IAQ assessments in two ship situations: ship-not-practising IAQ mitigation strategies and ship-after-practising IAQ mitigation strategies. The mitigation strategies involved open fresh air intake and overnight air flushing, which are the usual practices of IAQ mitigation strategies in buildings. The compliance of IAQ parameters was compared between the two situations, and data were statistically analysed using the Wilcoxon Signed Ranks test. Results showed a positive increment from 57.8% to 68.8% of IAQ parameters compliance after the ship practised the mitigation strategies. However, this study observed only two parameters showing significant changes in the increment, which were air movement (AM) and total volatile organic compounds (TVOC). In comparison, the other six parameters gave no significant changes between the situations. This study concluded that the IAQ mitigation strategies adapted from building practice managed to improve the IAQ onboard. However, more enhanced mitigation strategies needed to be implemented to provide better dilution of IAP and sufficient ventilation onboard. Therefore, this study emphasised the importance of having ship IAQ guidelines in order to advise effective IAQ mitigation strategies and good IAQ practices for ship setting. This will lead to an improvement in crew habitability and equipment performance onboard.

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Mora Simamora, A., Denih, A., Suriansyah, M. I.

Indoor Air Quality Detection Robot Model Based on the Internet of Things (IoT).

arXiv e-prints, (2025), arXiv-2505

This paper presents the design, implementation, and evaluation of an IoT-based robotic system for mapping and monitoring indoor air quality. The primary objective was to develop a mobile robot capable of autonomously mapping a closed environment, detecting concentrations of CO 2 , volatile organic compounds (VOCs), smoke, temperature, and humidity, and transmitting real-time data to a web interface. The system integrates a set of sensors (SGP30, MQ-2, DHT11, VL53L0X, MPU6050) with an ESP32 microcontroller. It employs a mapping algorithm for spatial data acquisition and utilizes a Mamdani fuzzy logic system for air quality classification. Empirical tests in a model room demonstrated average localization errors below 5% , actuator motion errors under 2%, and sensor measurement errors within 12% across all modalities. The contributions of this work include: (1) a low-cost, integrated IoT robotic platform for simultaneous mapping and air quality detection; (2) a web-based user interface for real-time visualization and control; and (3) validation of system accuracy under laboratory conditions.

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Collison, A. K., Byrne, M. A., Mcgrath, J. A.

Indoor air quality in naturally ventilated classrooms and offices in Ireland.

Building and Environment, Vol. **279**, (2025)

Indoor air quality in naturally ventilated offices and schools has significant implications for occupant health, well-being, and performance. This study conducted comprehensive multi-zone IAQ monitoring across 17 buildings - 8 office buildings, and 9 schools (51 environments in total) in Ireland, examining zonal and temporal variations in key parameters. Real-time monitoring of PM2.5, CO2, temperature, relative humidity, and total volatile organic compounds was complemented by passive sampling of formaldehyde, BTEX, pinene, limonene, and NO2. Results revealed distinct patterns in offices and schools, with CO2 concentrations in classrooms (median 1319 ppm) significantly exceeding office levels (median 714 ppm) during occupied periods. PM2.5 and NO2 concentrations were dependent on outdoor concentrations. PM2.5 showed a strong correlation with outdoor levels (r = 0.75) and 48 % of monitored days exceeded WHO 24-hour guidelines. Median formaldehyde concentrations of 19 µg/m3 and 20 µg/m3 in offices and

classrooms respectively were notably higher than previous studies. In contrast, limonene was detected in 76 % of schools compared to only 16 % of offices. Substantial variation was observed both between and within buildings, with some pollutants showing greater intra-building than inter-building variability. Both indoor and outdoor temperatures emerged as key factors influencing ventilation behaviour, particularly in classrooms where lower temperatures were associated with higher CO2 concentrations. The results highlight the ongoing challenges in balancing thermal comfort, ventilation and IAQ. Overall, these findings offer insights to guide policy development in naturally ventilated offices and schools, enabling evidence-based policy strategies to mitigate indoor air pollution exposure and enhance occupant health and well-being.

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Rosminahar, S. N., Mat, M. N. H., Rani, M. F. H., Wong Keng, Y., Akrami, M.

Influence of Air Changes Per Hours (ACH) on Human Thermal Comfort under Stratum Ventilation Setting in a Single Isolated Wardroom.

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, Vol. **130** n°(2), (2025), 90-99 p.

Proper ventilation is critical in hospital environments to ensure optimal conditions for healthcare professionals and patients. However, achieving a balance between contaminant removal and thermal comfort remains a challenge, particularly in enclosed spaces like wardrooms. This study investigates the relationship between air changes per hour (ACH) and human thermal comfort, specifically through the lens of the Predicted Mean Vote (PMV) metric in stratum ventilation settings. By utilizing Computational Fluid Dynamics (CFD) simulations, we explore various ACH scenarios to evaluate their effects on PMV. Our findings reveal that increased ACH rates often correlate with heightened discomfort among patients, highlighting the complex balance required in the ventilation design. In stratum ventilation systems, distinct PMV values emerge because of differing airflow dynamics, demonstrating that while some areas may meet comfort standards, discomfort persists elsewhere. This research emphasizes the significant impact of ACH on thermal comfort in healthcare settings, advocating for nuanced ventilation strategies that consider both contaminant removal efficiency and occupant comfort. The insights gained contribute to a deeper understanding of ventilation design in healthcare facilities, where a conducive indoor environment is vital for the well-being of both patients and staff.

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Nelson, J., Hatford, B.

Leveraging IoT Sensors for Real-Time Building Condition Monitoring and Predictive Analytics.

ResearchGate, (2025)

The integration of Internet of Things (IoT) sensors for real-time building condition monitoring and predictive analytics represents a transformative shift in facility management and operational efficiency. This study explores the deployment of various IoT sensor technologies-including environmental, structural, energy consumption, and occupancy sensors-within commercial buildings to continuously collect and analyze data. Real-time monitoring enhances operational efficiency, occupant comfort, and safety by providing immediate insights into building conditions. The application of predictive analytics powered by data collected from IoT sensors enables facility managers to anticipate maintenance needs, optimize energy consumption, and improve indoor air quality. By employing advanced machine learning algorithms, organizations can leverage historical and real-time data to create predictive models that inform decision-making processes and enhance maintenance strategies. Despite the numerous benefits, challenges such as data quality, security concerns, and integration with existing systems pose significant obstacles to effective implementation. This study addresses these challenges and discusses potential solutions, emphasizing the importance of data accuracy and security in the IoT ecosystem. Looking forward, the paper highlights emerging trends in IoT technology and predictive analytics, including advancements in sensor capabilities, enhanced data processing techniques, and the growing emphasis on sustainability in building management.

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Yuan, H., Li, N., Fan, W., Cai, H., Zhao, D.

Metal-Organic Framework Based Gas Sensors.

Advanced Science, Vol. **9** n°(6), (2022)

Abstract The ever-increasing concerns over indoor/outdoor air quality, industrial gas leakage, food freshness, and medical diagnosis require miniaturized gas sensors with excellent sensitivity, selectivity, stability, low power consumption, cost-effectiveness, and long lifetime. Metal-organic frameworks (MOFs), featuring structural diversity, large specific surface area, controllable pore size/geometry, and host-guest interactions, hold great promises for fabricating various MOF-based devices for diverse applications including gas sensing. Tremendous progress has been made in the past decade on the fabrication of MOF-based sensors with elevated sensitivity and selectivity toward various analytes due to their preconcentrating and molecule-sieving effects. Although several reviews have recently summarized different aspects of this field, a comprehensive review focusing on MOF-based gas sensors is absent. In this review, the latest advance of MOF-based gas sensors relying on different transduction mechanisms, for example, chemiresistive, capacitive/impedimetric, field-effect transistor or Kelvin probe-based, mass-sensitive, and optical ones are comprehensively summarized. The latest progress for making large-area MOF films essential to the mass-production of relevant gas sensors is also included. The structural and compositional features of MOFs are intentionally correlated with the sensing performance. Challenges and opportunities for the further development and practical applications of MOF-based gas sensors are also given.

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Von Domaros, M., Tobias, D. J.

Molecular Dynamics Simulations of the Interactions of Organic Compounds at Indoor Relevant Surfaces.

Annual Review of Physical Chemistry, Vol. **76** n°(Volume 76, 2025), (2025), 231-250 p.

With markedly different reaction conditions compared to the chemistry of the outside atmosphere, indoor air chemistry poses new challenges to the scientific community that require combined experimental and computational efforts. Here, we review molecular dynamics simulations that have contributed to the mechanistic understanding of the complex dynamics of organic compounds at indoor surfaces and their interplay with experiments and indoor air models. We highlight the rich interactions between volatile organic compounds and silica and titanium dioxide surfaces, serving as proxies for glasses and paints, as well as the dynamics of skin oil lipids and their oxidation products, which sensitively affect the quality of indoor air in crowded environments. As the studies we review here are pioneering in the rapidly emerging field of indoor chemistry, we provide suggestions for increasing the potentially important role that molecular simulations can continue to play.

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Adhikari, M., Saha, D., Chattopadhyay, D., Pal, M.

Rationally Designed Polypyrrole-Encapsulated MoO3 Hollow Nanostructures for Enhanced Formaldehyde Detection at Room Temperature.

ACS Applied Engineering Materials, Vol. **3** n°(5), (2025), 1302-1314 p.

Formaldehyde, a volatile organic compound (VOC) and ubiquitous indoor pollutant, is a known probable carcinogen that poses significant health risks even at low concentrations. Consequently, the development of selective detection methods for formaldehyde is imperative. This study focuses on a surface diffusion strategy to develop hollow nanostructured molybdenum trioxide (MoO3 HNs) encapsulated with polypyrrole (PPy) shell which can selectively detect sub-ppm formaldehyde at room temperature (25 °C) under elevated humidity conditions (65% RH). A self-template strategy was utilized, wherein Fe3+ cations played

a dual role as oxidizing agents to initiate pyrrole polymerization and as catalysts to facilitate the formation of hollow nanostructures through the nanoscale Kirkendall effect. MoP75 sensor has exhibited stable response-recovery up to 85% relative humidity (RH), with a significant sensitivity 6.5-fold (Ra/Rg) to 100 ppm of HCHO, along with rapid response (Γres = 13.34 s) and recovery (Γrec = 46.37 s). The enhanced sensing performance of MoP75 can be attributed to its high surface area (71.433 m2/g) and efficient charge transfer at the heterojunction interface. These results highlight the promising potential of MoP75 as a highly efficient material for selective formaldehyde detection at room temperature, rendering it suitable for practical applications.

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Baguley, D. A., Evans, G. S., Bard, D., Monks, P. S., Cordell, R. L.

Review of volatile organic compound (VOC) emissions from desktop 3D printers and associated health implications.

Journal of Exposure Science & Environmental Epidemiology, (2025)

Three-dimensional (3D) printing is a technique by which materials are continually added in layers to form structures. The technique has grown in popularity over the past decade and affordable desktop 3D printers are now widely used in schools, universities, businesses, and hospitals.

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Shields, E. P., Roberson, W. R., Ryan, J. V., Jackson, S. R.

The Use of Air Pollution Controls to Reduce the Gas-Phase Emissions of Per- and Polyfluoroalkyl Substances from a Fluoropolymer Manufacturing Facility.

Environmental Science & Technology Letters, (2025)

The efficacies of a thermal oxidizer and carbon adsorption beds used as air pollution control technologies at a fluoropolymer manufacturing facility were evaluated for nonpolar volatile fluorinated compounds (VFCs) using Other Test Method (OTM)-50. The target compounds for the synthesis of OTM-50 include industrial fluorocarbons, common products of incomplete combustion, reaction byproducts, and common refrigerants. The thermal oxidizer's emissions were found to contain tetrafluoromethane (CF4). Emissions from the carbon adsorption beds used to scrub the fugitive air emissions for two vinyl ether synthesis facilities were sampled, and the analyses showed that the compounds with boiling points below 100 °C were not effectively adsorbed. This research shows that the facility's thermal oxidizer is effective at destroying high-concentration streams of perfluoroalkyl substances (PFAS) and that the carbon beds can reduce emissions for compounds with boiling points above 100 °C.

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