Bulletin de veille QAI
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Objectif : *Qualité de l'air intérieur*

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Google Scholar, Lens, WoS

Allena, N., Anto, A. M., Espinosa, L., Khanal, S., Vakde, T.

Addressing Environmental Factors in COPD: The Role of HEPA Filters in Indoor Air Quality.

Int J Respir Pulm Med, Vol. **12**, (2025)

COPD is a major public health issue globally, resulting in significant morbidity, loss of productivity, and increased health expenditure. Air pollution is considered the primary factor leading to the development and progression of COPD. While the role of outdoor air pollution was well outlined, studies have looked at how indoor air quality and indoor air pollution can cause or worsen the disease. Even though we know that outdoor air pollution has contributed to COPD, the question remains: how do outdoor air pollution and an increased outdoor air pollution load impact indoor air quality, and how will that impact COPD development and progression, and can indoor air filters tackle that? This narrative review focuses on air pollution, the air quality index, and the impact of environmental pollution on indoor air quality and COPD. We also describe the role of the HEPA filters in tackling indoor air pollution, their mechanism, and their impact on COPD and control of indoor air pollution.

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Sousan, S., Wu, R., Popoviciu, C., Fresquez, S., Park, Y. M.

Advancing low-cost air quality monitor calibration with machine learning methods.

Environmental Pollution, Vol. **374**, (2025)

Low-cost monitors for measuring airborne contaminants have gained popularity due to their affordability, portability, and ease of use. However, they often exhibit significant biases compared to high-cost reference instruments. For optimal accuracy, these monitors require calibration and validation in their specific environment using expensive reference instruments, which are often scarce and costly. This study proposes machine-learning calibration methods that utilize a single high-cost instrument as an active reference to improve the accuracy of large networks of low-cost monitors. Three machine learning models—linear regression, random forest, and Gradient Boosting Regression (GBR)—were employed. The proposed approach was tested in a controlled chamber under two conditions: environmental simulations with salt- and dust-based aerosols and occupational settings using three electronic cigarette (ECIG) brands. The study involved thirty low-cost GeoAir2 monitors, divided into ten groups of three. Initially, all groups were collocated with a high-cost monitor using Aerosol A to develop prediction and regression models. These models, along with intrinsic error measurements from one group, were then applied to improve data accuracy for the remaining groups using Aerosol B. The results demonstrated substantial improvements in accuracy, with r2 values ranging from 0.91 to 1.00 and RMSE reductions of up to 88 %, depending on the model and aerosol type. GBR consistently provided the highest accuracy and performance, particularly for complex, nonlinear patterns, while linear regression offered a faster, computationally efficient alternative suitable for less demanding scenarios. Random forest models performed moderately well, balancing accuracy and complexity. These methods provide a scalable and cost-effective solution for deploying networked low-cost sensors. Further research is needed to validate these findings in outdoor environments with meteorological and spatial influences, and indoor occupational settings where humidity effects may play a role.

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Nguyen, T.-P.

AIoT-based indoor air quality prediction for building using enhanced metaheuristic algorithm and hybrid deep learning.

Journal of Building Engineering, Vol. **105**, (2025)

This study presents an artificial intelligence of things (AIoT)-based framework for intelligent building indoor air quality (IAQ) prediction and management, addressing the critical need for real-time monitoring and control to ensure healthier indoor environments. Poor IAQ poses significant risks to human health and productivity, making accurate predictions essential for proactive air quality management in smart buildings. To enhance predictive accuracy, a hybrid deep learning algorithm is developed, integrating enhanced particle swarm optimization (EPSO) for hyperparameter tuning and a convolutional neural network-long short-term memory (CNN-LSTM) model for feature extraction and temporal pattern learning, which demonstrates superior predictive capabilities. By fine-tuning its hyperparameters, the EPSO approach improves prediction performance and guarantees reliable and effective forecasts. Several datasets are used to assess the suggested framework, with particular attention paid to important IAQ indicators, including particulate matter 2.5 (PM2.5), humidity, temperature, CO2, and total volatile organic compounds (TVOC). The developed EPSO-CNN-LSTM framework is rigorously evaluated and compared with traditional deep learning models, including recurrent neural network (RNN), CNN, gated recurrent unit (GRU), LSTM, and traditional CNN-LSTM model, using comprehensive evaluation criteria across multiple datasets. The experimental results demonstrate the proposed framework's capability to outperform these methods in terms of prediction accuracy and generalization across diverse IAQ scenarios. The proposed framework holds significant potential for real-time indoor air quality monitoring and control in intelligent building frameworks, which contribute to healthier and more sustainable environments. This research establishes a strong foundation for deploying AIoT technologies in advanced IAQ management and predictive analytics.

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Oo, G. M., Kotmool, K., Mongkolwongrojn, M.

Analysis of Indoor PM2.5 Contaminants Based on Outdoor Wind Velocity Through Different Infiltration Types.

Journal of Engineering, Vol. **2025** n°(1), (2025)

Nowadays, indoor PM2.5 concentrations have become a significant factor affecting indoor air quality (IAQ) and a major public concern, particularly with the rise of haze in Thailand and globally, as PM2.5 can penetrate human lungs. This research analyzes the dispersion of PM2.5 from outdoors to indoors using a fluid dynamics simulation framework that combines the Eulerian approach for continuous flow, the Lagrangian approach for particulate matter dispersion, and the RNG k-ε turbulent model for airflow. The study is aimed at protecting indoor environments from harmful exposure to PM2.5 from outdoor contaminants and improving IAQ. Primarily, three different infiltration types and shapes are studied to determine the minimum optimal positive room pressure, based on the impact of ambient wind velocity on indoor PM2.5 concentrations from outdoor pollutants. A minimum optimal pressure of 3.6?Pa and 27 air changes per hour (ACH) is sufficient to achieve a PM2.5-free indoor environment for all infiltration models. Furthermore, higher wind speeds can reduce indoor PM2.5 concentrations due to the increased momentum of particles. This research technique is implemented in the practical field study conducted within the laboratory room of the 55-Year Chalermprakiat Building. As a result, the investigated room, with an infiltration area of 0.06?m2 and a rate of 0.0036?m3/s, will be certified as a clean room by achieving an optimal minimum pressure of approximately 0.01?Pa. This research will help achieve cleaner and safer indoor environments for any building by leveraging the optimal minimum pressure of cleanroom technology, provided that the infiltration rate and ambient wind velocity are accurately determined.

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Vignesh Raju, R., Jeeva, N., Kekana, M. C., Fadugba, S. E., Swaminathan, R.

Analytical techniques for understanding biofilm modeling in indoor air quality management.

Results in Control and Optimization, Vol. **19**, (2025)

This study presents a theoretical and mathematical framework for developing a dimensionless model to enhance the removal of volatile organic compounds (VOCs) through (botanical) biofiltration in indoor environments. Although biofiltration is a promising strategy for the control of indoor air pollution, the precise mechanism of VOC removal remains not well understood. The proposed model is formulated using nonlinear differential equations under specified boundary conditions to represent biofilm mass balance concentrations. To obtain approximate solutions, Homotopy perturbation and Akbari-Ganji analytical techniques are applied. In addition, numerical simulations are performed using MATLAB® and compared with analytical results to validate precision. The findings indicate that optimizing the biofilm thickness and reaction rates significantly enhances the removal efficiency of VOCs. Improves understanding of the behavior of biofilms through advanced mathematical analysis, contributing to the development of more effective biofiltration strategies for improved indoor air quality management.

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Braga, M. P., Niza, I. L., Broday, E. E.

Assessment between indoor environmental quality aspects and productivity in buildings: a systematic literature review.

Building and Environment, Vol. **278**, (2025)

Due to changes in people's living and working patterns, studies into indoor environmental quality (IEQ) have become increasingly relevant due to their influence on people's health, comfort and, above all, productivity. By selecting studies using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this study carried out a literature review to identify the main models that assess people's productivity based on the four tangible aspects of IEQ (indoor air quality, thermal, acoustic and visual comfort). Three research questions were answered after using bibliometric analysis, hierarchical clustering, and meta-analysis. The main conclusions of this study are: (i) Seventy-three productivity models related to aspects of IEQ were identified, involving twenty-four different parameters, the temperature being the most recurrent one in the predictive models; (ii) The dendrogram, generated by the hierarchical clustering, formed six different groups, where parameters related to thermal comfort and indoor air quality remaining together; (iii) After analyzing the main characteristics of each model, verifying their main strengths and weaknesses, it was verified that the representativeness of the sample, climatic and cultural biases, psychosocial factors, subjective perceptions and the scope of the IEQ aspects, the data collection methodology and statistical validation are determining factors for the reliability of the models. (iv) Meta-analysis consolidated studies on the correlation of productivity models, revealing a predominance of positive correlations but with high heterogeneity (I^2 = 98.39 %). This suggests a publication bias, suggesting an under-representation of non-significant or negative results. The presence of this variation reflects the need to consider contextual factors when discussing IEQ aspects, which can depend on local characteristics, cultural expectations and occupants' habits.

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Giraldo-Pérez, J. P., Bruse, J. L., Odriozola, J., Mejía-Gutiérrez, R.

Balancing indoor air quality and ventilation efforts via deep reinforcement learning: An agent-based approach applied to an office building.

Energy and Buildings, Vol. **335**, (2025)

The COVID-19 pandemic highlighted the critical role of Heating, ventilation, and air conditioning (HVAC) systems in mitigating airborne disease transmission within indoor environments. While increasing active building ventilation improves Indoor Air Quality (IAQ), it also leads to higher energy consumption. With buildings projected to account for over 30 % of global energy demand by 2050, balancing IAQ and energy efficiency has become a pressing challenge for building designers and operators. However, existing research has predominantly focused on optimizing heating and cooling aspects of HVAC systems for thermal comfort and cost reduction, often neglecting optimal ventilation control for IAQ and energy efficiency. This paper presents a novel approach that combines Deep Reinforcement Learning (DRL) with

Agent-Based Modeling (ABM) to optimize an open-loop HVAC ventilation control in office buildings. Unlike standard driven methods that rely on static equations and do not adapt to realistic occupancy patterns, our DRL agent takes into account stochastic user behavior simulated within the ABM environment. Simulation results demonstrate that, at times, the applied ventilation standard exceeds common target carbon dioxide (CO2) levels and tends to over-ventilate on less or sporadically used rooms, leaving potential for energy savings associated with ventilation efforts. A brute-force (BF) approach, optimizing ventilation rates iteratively using the ABM environment, avoided over-ventilation best while maintaining CO2 levels closest to the desired targets. However, the DRL agent achieved similar performance while requiring substantially less computational efforts than the BF method. This work contributes to the development of intelligent HVAC control systems that can balance IAQ and ventilation efforts better than static ventilation guidelines and thus promotes post-pandemic, sustainable building design and operation.

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Bose, R., Gujar, S., Patil, N., Dwivedi, A. K., Vemuri, K., Chaudhari, S.

Comparative Analysis of Construction-Related Air Pollution in Indoor and Outdoor Environments.

Pollution and Its Minimization. ICEPP 2023

This paper presents a comparative analysis of air pollution patterns near a construction area which is approximately 300 m from a residential apartment located in Hyderabad, India. Internet of Things (IoT) based air pollution nodes were designed and deployed in both indoor and outdoor environments across four adjacent blocks near the construction site. An additional node was also deployed away from the direct line of the site of the construction area for comparison. The study investigated the levels of PM2.5, PM10, temperature, and humidity as outdoor parameters, and PM2.5, PM10, CO2, VOC, temperature, and humidity as indoor parameters. Also, analyzing correlation coefficients and box plots for detailed analysis. The findings revealed that air pollution spreads over a wide area, as a function of the scale of construction i.e. (high-rise buildings) and wind ducts. The experiment aimed to substantiate empirical data through analysis of residents' concerns about breathing difficulties and health issues due to restricted outdoor activities from high construction-based air pollution. The study will help policymakers and construction companies take appropriate construction activity measures to reduce health hazards.

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Das, S., Indu, G., Nagendra Sm, S., Vardoulakis, S.

Comparative Analysis of Indoor Air Quality and Health Risk Assessment in Academic Workspaces in India and Australia.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

Indoor air quality (IAQ) in workplaces significantly impacts occupational health and productivity, necessitating comparative evaluations across diverse environments. This study investigates particulate matter (PM) concentrations in indoor academic workspaces in Chennai, India, and Canberra, Australia, using the GRIMM 11D aerosol spectrometer. A 12-hour monitoring campaign was done in IIT Madras, India, and ANU, Australia for 3 days during the post-winter (Spring) season. It measured the PM1, PM2.5, PM4, and PM10 levels in the indoor workspaces offering insights into PM concentrations.The average PM concentrations in Chennai were significantly higher than in Canberra. Indian workplaces recorded PM1, PM2.5, PM4, and PM10 levels of 4.03±1.09, 8.28±2.15, 12.36±4.26, and 15.83±6.43 (µg/m³), respectively. Corresponding Australian values were notably lower, at 1.53±0.47, 2.82±1.02, 3.52±1.69, and 4.14±2.72 (µg/m³), respectively. Spikes in PM10 levels in both regions suggest occasional localized pollution events or episodic pollutant intrusions, influencing PM concentrations. Additionally, the fine PM fractions (PM1 and PM2.5) were more prominent in Canberra, indicating potential variations in pollutant sources and infiltration rates.Health risk assessments were performed by simulating lung deposition dosages for males and females using the ‘Symmetric Lung’ configuration within the Multiple Path Dosimetry Model (MPPD). The model revealed stark contrasts in PM lung deposition doses between the two regions, with Indian

workplaces presenting significantly higher health risks. In Chennai, male dosages for PM1, PM2.5, PM4, and PM10 were 4.23, 22.16, 38.98, and 56.41 µg, respectively, while females experienced slightly lower dosages of 2.79, 12.99, 23.33, and 34.70 µg. In Canberra, the respective values for males were 1.61, 5.80, 9.14, and 12.33 µg, and for females, 1.05, 3.40, 5.41, and 7.46 µg. These findings highlight a significantly higher health risk for workers in Chennai, with females in both locations receiving lower doses due to smaller lung capacities and breathing rates.This pilot study brings out substantial regional differences in IAQ, shaped by environmental factors, building ventilation standards, and external pollutant sources and infiltration rates. Elevated PM concentrations in Chennai signal a pressing need for interventions to enhance workplace air quality, such as improved filtration and ventilation systems and awareness campaigns. Meanwhile, the finer PM fraction in Canberra warrants attention due to its deeper penetration into the respiratory tract and long-term health implications.Further research should address long-term exposure risks, seasonal variability, and effective mitigation strategies to improve IAQ and safeguard academic workforce health in diverse geographical settings.

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Shi, H., Yang, Y., Liu, Y., Xu, W., Li, S.

Cu2O/Cu-ZnO@ZnO microspheres for ultrasensitive detection of formaldehyde at room temperature.

Applied Surface Science, Vol. **698**, (2025)

The formation of p-n junctions in semiconductor materials enhances gas-sensing performance through regulated interfacial charge transfer dynamics to improve sensitivity and selectivity. Based on this concept, controlled Cu-doping enables the rational design of core–shell Cu-ZnO@ZnO homojunction microspheres and hierarchical Cu2O/Cu-ZnO@ZnO microspheres. The Cu-ZnO@ZnO and Cu2O/Cu-ZnO@ZnO microspheres exhibit distinct formaldehyde sensing mechanisms from pristine ZnO. We demonstrate the formation of the p-n homojunction structure in Cu-ZnO@ZnO by using surface photovoltage and surface photovoltage transient measurements. In addition, the interfacial charge transfer kinetics of Cu-ZnO@ZnO and Cu2O/Cu-ZnO@ZnO materials were investigated. The Cu2O/Cu-ZnO@ZnO sample exhibits ultra-high sensitivity to low concentrations of HCHO, with theoretical limits as low as 124 ppb. Concurrently, the sample exhibited a favorable selective response to formaldehyde and long-term stability.

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Ramadan, M. N. A., Ali, M. a. H., Alkhedher, M.

Development of a federated learning-enabled IoT framework for indoor air quality and HVAC optimization in healthcare buildings.

Journal of Building Engineering, Vol. **107**, (2025)

Maintaining optimal indoor air quality (IAQ) in healthcare buildings is essential for occupant health, energy efficiency, and HVAC system performance. This paper presents a novel IoT-based air quality monitoring and ventilation control system powered by federated learning (FL) for real-time IAQ management. The system deploys multi-sensor IoT units to monitor PM2.5, PM10, CO2, CH2O, TVOC, temperature, and humidity in emergency rooms, doctors' offices, and reception areas across three hospitals. A central hub dynamically adjusts HVAC settings based on real-time sensor data and predictive analytics, ensuring proactive air quality management. Addressable RGB indicators provide real-time IAQ displays and 30-min predictive warnings, enabling timely interventions. To enhance scalability, security, and computational efficiency, we introduce the Hierarchical Adaptive Federated Aggregation (HAFA) algorithm, which improves non-IID data processing and model accuracy in decentralized IAQ monitoring. HAFA achieves 90.8 % predictive accuracy (LSTM) and 88.0 % (CNN), outperforming conventional FL models. Additional performance metrics (R2 = 0.87, RMSE = 0.09) validate its robustness. The system integrates LoRaWAN for low-power, long-range communication and HTTPS encryption for secure cloud-based data transmission. This paper demonstrates a scalable and intelligent IAQ control system for sustainable building management in healthcare facilities. By integrating IoT, federated learning, and HVAC

optimization, it provides an energy-efficient, secure, and adaptive solution for indoor air pollution control in smart healthcare environments.

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Agus, A., Almamalik, L., W, C.

Development of a Smart Air Pollution Detection System Utilizing MQ2 Sensor and Node MCU ESP8266 with Telegram Integration.

Jurnal Ekonomi Manajemen Sistem Informasi, Vol. **6** n°(3), (2025), 1634-1640 p.

<p>The rapid increase in air pollution, particularly in indoor environments, poses significant health risks. This study aims to develop a smart air pollution detection system using the MQ2 gas sensor integrated with the NodeMCU ESP8266 microcontroller and Telegram messaging application for real-time monitoring and notification. The system is designed to detect harmful pollutants, specifically cigarette smoke, and notify users when pollution levels exceed 100 parts per million (PPM). The MQ2 sensor measures the concentration of gases, while NodeMCU ESP8266 processes the data and communicates with the Telegram API to send alerts. The system was tested at the Banjaran District Office, where it demonstrated high accuracy in detecting indoor air pollution, with a response time of approximately 2 seconds and an alert accuracy of 100%. The results show that the system provides an effective and affordable solution for real-time air quality monitoring, contributing to improved indoor environmental health. Future enhancements could include expanding the system's detection capabilities to monitor additional pollutants and integrating it into larger IoT-based environmental systems.</p>

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Lee, Y., Kim, Y.-S., Lee, G., Lee, H., Kim, Y.-J., Han, B.*, et al.*

Development of an Electrostatic Precipitator With a Novel Dry-Cleaning Apparatus for Building Ventilation Systems.

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

Electrostatic precipitators (ESPs) offer a durable solution for enhancing indoor air quality. However, traditional cleaning techniques often pose financial burdens and result in issues such as electrode degradation and particle re-entrainment, which is crucial for building management. In this study, we introduced an ESP with a novel dry-cleaning apparatus tailored for indoor air purification systems. The novel cleaning apparatus utilized a combination of compressed air-blasting and vacuum suction mechanisms to dislodge and extract particles from the collection plates. Moreover, the ESP incorporated a two-stage design featuring a charger equipped with carbon brush ionizers and a collector comprising carbon ink?coated plastic plates. This design not only mitigates ozone emissions but also reduces installation costs. Our results revealed a consistent cleaning efficiency exceeding 98% under optimal operational conditions, restoring reduced collection efficiency due to contamination. Finally, we conducted field demonstration experiments in subway stations. We retrofitted an air handling unit with our ESP system and dry-cleaning apparatus, showing a collection efficiency of 99.4% for PM1. To validate the efficacy of our dry-cleaning apparatus, we conducted a 16-day test at a vent outlet of a subway station. The field demonstration of the dry-cleaning apparatus showcased nearly flawless recovery of collection efficiency to the initial state. In summary, our investigation represents a significant advancement in overcoming the prevailing challenges associated with ESP utilization in indoor air purification applications.

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Zúñiga, G. R., Del Valle, G. B., Lesbros, G. H., González, H. D. C.

Diseño, construcción y caracterización de un monitor de co2 para la calidad del aire de interiores y ventilación, compatible con tres sensores, con integración iot, autoprueba y autodiagnóstico (Design, building and characterization of a co2 monitor for indoor air quality and ventilation, tri-sensor compatible, with iot integration, self-testing, and self-diagnosis).

Pistas Educativas, Vol. **46** n°(149), (2025)

A CO2 monitor to evaluate indoor air quality and ventilation is presented. The monitor is compatible with three CO2 sensors, is low-cost, and easy to manufacture. It has IoT integration, self-test, and self-diagnostic capabilities. Additionally, it includes visual and audible alarms for different CO2 levels. The design of the electronic circuit and casing ensures easy production and assembly. An IoT-enabled NodeMCU board facilitates remote monitoring and data storage through ThingsBoard. The configuration mode allows users to set up Internet access and IoT connectivity. Upon startup, the monitor performs a software test for the buzzer and RGB LED and provides diagnostic messages for troubleshooting. Controlled experiments validated the monitor's accuracy and reliability. A pilot study in a classroom demonstrated its practicality and effectiveness, highlighting the importance of adequate ventilation. All information to replicate the CO2 monitor is in a public repository.

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Wu, M.-F., Zhong, M.-Z., Tsai, H.-Y., Tseng, Y.-S., Wen, C.-Y.

Edge-Docker–Based Architecture for Intelligent Indoor Air Quality Management With Sensing Calibration and Automatic Controlling.

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

Reports show that poor indoor air quality can be harmful to vulnerable groups and lead to various health problems. To address this problem, this work proposes a management architecture for enhancing indoor air quality by integrating the analytical learning models and regulation of indoor and outdoor pollutant concentrations, which coordinates the activation or deactivation of the pollutant control devices. The proposed system incorporates predictive and calibration functionalities to enhance overall system stability and effectiveness. This work tests the prediction accuracy of multilayer perceptron and recurrent neural network models. The experimental results show that the bidirectional long short-term memory (Bi-LSTM) with a land use regression (LUR) based feature extraction model achieves the best predictive performance with a mean absolute error of 5.74 and a mean absolute percentage error of 15.7%, respectively. Comparing the existing Bi-LSTM work for PM2.5 prediction, the proposed Bi-LSTM model with feature selection delivers superior accuracy by about 14.58% in terms of the mean absolute error performance. To further assess the system feasibility, a self-designed air box with the Docker technology is developed to customize system parameters for various monitoring needs. The system has undergone validations through Ansys indoor airflow simulation software and scenario testing, demonstrating its effectiveness and great promise for the rapid removal of indoor pollutants.

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Kek, H. Y., Tan, H., Dzarfan Othman, M. H., Abdul Wahab, N. H., Wong, K. Y.

Effect of air change rate on the particle dispersion in single-bed medical ward: A numerical study.

AIP Conference Proceedings, Vol. **3056** n°(1), (2025)

A medical ward is a healthcare facility that is designed to accommodate a group of communicable and vulnerable patients. However, the simultaneous use of the inpatient care facility by patients, visitors and healthcareworkers has increased the chances of contracting hospital-acquired infection (HAI). A ventilation strategy is regarded as the primary measure to provide fresh air and remove indoor pollutants. To minimise the indoor transmission risk of cross-infection, the understanding of the dispersion of pathogenic particles inside the medical ward was crucial. Therefore, the objective of this study is to examine the effect of air change rate in suppressing the particle dispersion in the vicinity of a patient considering different supplied air velocities from a ceiling-mounted diffuser. In this study, a commercial computational fluid dynamics (CFD) software was utilised to investigate the dispersion characteristics of coughed particles sourced from a healthcare worker. A validated RNG k-ε airflow model and the discrete phase model were adopted to simulate the airflow velocity and the dispersion of airborne particles accordingly. Findings revealed that cases 1, 2, 3, and 4 (supplied air velocity of 0.12m/s, 0.25m/s, 0.49m/s and 0.98m/s) have recorded the reaching distance of 1.5m, 0.75m, 0.65m and 1.1m, respectively. The current study indicated that the

airflow velocity of the supply diffuser is critical in reducing the particle settlement in the vicinity of the patient and lowering the associated infection risk, where an air change per hour (ACH) of 6 in the medical ward is insufficient to remove the pathogenic particles. This study also deduced that the increase of ACH to 12 and 24 could lead to the higher efficiency of particle removal in controlling the spread of infection and noted an adverse impact during the operation of 48 ACH.

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Kanwate, A. D., Kathwate, L. H., Chandak, V. S., Panse, V. R.

Effect of Annealing Temperature on Chemiresistive Ammonia Gas Sensing Properties of Nickel Oxide Thin Films Deposited by SILAR.

International Journal of Scientific Research in Science and Technology, (2025)

The study focuses on the development of nickel oxide (NiO) thin films on silica glass plate by using SILAR techniques. After an hour of annealing at distinct temperatures (200 C, 300 C, and 400 C), the films' optical, structural, morphological, and ammonia gas sensing characteristics were examined. A cubic unit cell structure with an crystallite size of 20–55 nm was shown by the XRD pattern. SEM images were observed of randomly oriented rope-shaped and spherical nanoparticles. The UV-Vis absorption spectra showed that as annealing temperature increasesethe energy band gap decreases. The chemiresistive ammonia gas sensing study found thatfilms annealed at minimum temperatures 100 C showed a 31.4% response, while those annealed at high temperatures showed a higher response. The gas sensing response of the nickel oxide films annealed at 400 C is 68.4%, which is the highest among all the samples. The optimized film sensors showed a linear response for exposed gas, which eventually shifted to saturation. The results suggest that these films could be effective for sensing ammonia gas at low temperatures.

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Oni, E. A., Ayanlola, P. S., Aremu, A. A., Oladapo, O. O., Lawal, M. K.

Effect of Chronic Exposure to Low-Level Radon Gas from Tertiary Institutions Workplaces in Western Nigeria.

Journal of Applied Sciences and Environmental Management, Vol. **29** n°(3), (2025), 831-840 p.

The carcinogenic effect of exposure to radon on human health is a concern globally. Hence, the objective of this paper was to assess the effect of chronic exposure to low-level radon gas from tertiary institutions workplaces in Western Nigeria using dosimetric and Monte Carlo simulation (MCS). Data obtained show that 84.09% of 132 workplaces investigated are within 100 Bqm-3 (0.01 WL) action level recommended for indoor radon. The average values obtained for the estimation of excess lifetime cancer risk at each studied institution ranged from 0.28% to 0.50% for the dosimetric method and 0.32% to 0.58% for the probabilistic method. The sensitivity analysis revealed that annual occupational exposure to radon decay products is the highest contributor to the risk estimate, followed by the mean life time duration, while the risk factor contributes least. Thus, chronic exposure to low-level indoor radon can lead to lung cancer, most especially for a non-smoker, at a certain stage in life if adequate precautionary measures are not taken to reduce the concentration of indoor radon. Hence, the use of air conditions should be minimized at the workplaces by cultivating a healthy life style of allowing sufficient diffusion of indoor radon-induced air with outdoor air.

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Ng, D. K. T., Provenaz, W., Goh, J. S., Wee, K. P. X., Gu, Z., Wang, H.*, et al.*

Environmental influences on NDIR CO2 gas sensor using 20 % ScAlN-based pyroelectric detector chip.

Sensors and Actuators B: Chemical, Vol. **439**, (2025)

CO2 gas sensors are adopted in various manufacturing industries, medical sectors and also for indoor air quality measurement. Their functions range from concentration monitoring for product quality to detecting

hazardous levels for safety. Having a robust CO2 gas sensor is important, but these sensors can be affected by temperature and humidity in the environment. Here we demonstrate an NDIR CO2 gas sensor based on 20 % ScAlN-based pyroelectric detector chip, tested under different environmental conditions. Despite absolute signal output drop when surrounding temperatures increase, measured results show that CO2 gas response remains the same. Moreover, relative humidity (RH) does not seem to have much effect on the response of this NDIR CO2 gas sensor. Response times stay at ~1–2 s despite changes in environmental conditions. This sensor is also tested continuously for 100 hours to observe its signal variation over long hours. We note signal variation of ~± 0.44 % during the first 40 hours with subsequent variation increase to ~ ± 1.7 % at the 50th hour. Robustness of CO2 gas sensing with 20 % ScAlN-based pyroelectric detector chip is also observed by measuring the gas responses of 5 detector chips obtained from 5 different locations within an 8-inch wafer, measuring CO2 gas sensing performance uniformity ~0.48 % within an 8-inch wafer. The results obtained will allow us to have further insights and understanding on the potential and practicality of NDIR gas sensors based on 20 % ScAlN-based pyroelectric detectors when subjected to different environmental conditions.

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Grosu, M. C., Visileanu, E., Albulescu, R., Ene, G. A.

Evaluation of Exposure to the Action of Plastic Particles in the Industrial Environment.

In: The 19th Romanian Textiles and Leather Conference. Sciendo; 2025. 275-281 p.

The global pollution problem is difficult to assess and manage. One of the sources of pollution is theemission of micro and nano plastic particles, both in the air, water, and soil, whose impact on human healthis increasingly being analyzed in the academic and scientific community. While the harm caused bymicroplastics is not fully known , there is a heightened concern over their role as favorizing of human exposureto toxic chemicals. Regardless of their nature, as anthropogenic particles, with limited biodegradation, thepenetration of NPMs into the human body, by different routes (either by inhalation, ingestion, or dermalcontact), creates risks to human health, which translates into increased levels of toxicity to the digestive,respiratory, nervous, immune, reproductive, endocrine and cardiovascular systems. Moreover, the highcontact surface area and high hydrophobicity confer the potential for MNPs to act as a vector for highadsorption of environmental pollutants, including organic pollutants, heavy metals, and pathogenicmicroorganisms, leading to unexpected consequences when they enter the human body. The paper presents theresults of testing the cytotoxic effect of PES MNPs on human cells and also evaluates the irritant and corrosiveeffect level of those MNPs on Human Skin. The results show that the collected PES particles do not representa major risk factor for dermal exposure on lesion-free integument. Anyway, potentail cannot be excluded forexposure to open wounds or exposures occasioned by admission via other routes (e.g. respiratory), butexposure may not give rise to risks above the irritant level.

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Richter, M., Schühle, F.

Experimental determination of 7-day uptake rates for diffusive sampling of 86 volatile and semi-volatile organic compounds relevant for indoor air monitoring and investigation on their sensitivity to exposure time and indoor climate.

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

This study aimed to experimentally determine uptake rates for 86 indoor relevant volatile and semi-volatile organic compounds (VOC, SVOC) for the passive sampler type Perkin Elmer/Markes™ with Tenax® TA as sorbent, which was used in the German Environmental Survey on Health (GerES VI) carried out by the German Environmental Agency (UBA) in the years 2023–2024. For this purpose, single reference gas atmospheres of 76 pure VOCs (liquid at room temperature) and a group of 10 SVOCs and VOCs (solid at room temperature) were generated using two generation procedures. By exposing the samplers to individual components, it was ruled out that interactions in a mixture have an influence on the uptake rate. Another aspect was to precisely describe the methodology and the resulting uncertainties, as there are

gaps in the literature in this regard. The selection of the compounds was based on the findings of the preceding GerES V study for which data was missing or needed to be verified. In each experiment, a number of six passive samplers was exposed to the test gas atmospheres in dynamically operated exposure chambers for seven days. The sensitivity of the uptake rates of a group of 10 selected VOCs to variations in exposure time, ambient temperature, and air humidity in a multi-component reference gas atmosphere was investigated. Here, a decrease in the uptake rate with the exposure time could be observed stabilising from the fifth day of exposure onwards. A significant effect of temperature and humidity on the uptake rate was not apparent. The determined uptake rates exhibit uncertainties of < 20 % for 71 substances, and < 10 % for 51 substances which are also in good agreement with the literature, if already published elsewhere. The quantity of investigated substances, the detailed description of the methodology used to determine the uptake rates complemented by the respective uncertainties, as well as the compilation of comparative data, contribute to a better assessment of the quality and relevance of such data, which had not been published before.

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Walia, S., Singh, S.

Exploring the Intersection of Interior Design and Indoor Air Quality: A Bibliometric Study.

Advances in Construction Management

The article provides a bibliometric study of the research landscape about interior design and indoor air quality. This study aims to offer a comprehensive analysis of publication trends, influential research, collaboration patterns, research themes, and emerging trends within the specified subject. The analysis employs the Scopus database, which encompasses 1984 to 2023. This study aims to ascertain the growth rate of research, analyze citation patterns, investigate collaboration among writers, and examine trends in keywords. The results demonstrate a growing interest in the correlation between interior design and indoor air quality, as seen by a recent increase in research productivity. The analysis focuses on critical contributors, notable scholarly works, and prominent academic journals. Through addressing specific research inquiries, this study makes a valuable contribution towards comprehending the research terrain, discerning research priorities, and advocating for evidence-based approaches to enhance indoor air quality and promote the well-being of occupants.

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Mshragi, M., Petri, I.

Fast machine learning for building management systems.

Artificial Intelligence Review, Vol. **58** n°(7), (2025)

Building management systems (BMSs) are increasingly integrating advanced machine learning (ML) and artificial intelligence (AI) capabilities to enhance operational efficiency and responsiveness. The transformation of BMSs involves a wide range of environmental, behavioural, economical and technical factors as well as optimum performance considerations in order to reach energy efficiency and for long term sustainability. Existing BMSs can only provide local adaptability by creating and managing information for a built asset lacking the capability to learn and adapt based on performance objectives. This research provides a comprehensive review of ML techniques in BMSs, with particular emphasis and demonstration of fast machine learning (FastML) techniques in a real-case study application. The study reviews optimization methods for ML algorithms, focusing on Long Short-Term Memory (LSTM) networks for energy consumption forecasting and exploring solutions that leverage hardware accelerators for low-latency and high-throughput processing. The High-Level Synthesis for Machine Learning (HLS4ML) framework facilitates deployment of fast machine learning models with BMSs, achieving substantial gains in hardware efficiency and inference speed in resource-constrained environments. Findings reveal that HLS4ML-optimized models maintain accuracy while offering computational efficiency through techniques like pruning and quantization, supporting real-time BMS applications. This research significantly contributes to the

development of intelligent BMSs by integrating ML algorithms with advanced hardware solutions, ultimately improving energy management, occupant comfort, and safety in modern buildings.

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Huang, C., Kwok, H. H. L., Poon, K. H., Wu, Z., Hou, F., Ma, J.*, et al.*

Graph-based spatial–temporal prediction and feature interaction analysis of CO2 and occupant in large indoor space.

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

With increasing focus on human health, Indoor Air Quality (IAQ) research has become crucial as people spend over half of their lives indoors. Carbon Dioxide (CO2) is a key IAQ parameter associated with Sick Building Syndrome (SBS). Despite the existing connection between indoor occupants and CO2 levels, research on predicting these parameters has largely been conducted in isolation. Most existing studies have not fully analyzed the complex interplay between environmental factors and occupant presence, often relying on historical data without considering intricate feature interactions. This paper introduces a novel learning-based framework to construct spatial–temporal graphs for large indoor environments, interlinking multi-sourced time series into a single graph. To address sensor resolution disparities, we incorporate time-lag nodes, resolving the Different sEnsor at Different Time (DEDT) problem and preserving in high-resolution data integrity. Our proposed model, the Attention-based Spatial–Temporal Graph Convolutional Recurrent Unit (AST-GCGRU), incorporates an encoder–decoder structure, can dynamically capture and validate complex interactions between CO2 and occupants. The model enhances adaptability and robustness in predictive tasks, improves prediction accuracy by 28.5% over baselines. Specifically, for CO2 and occupant nodes, accuracy improvements reach 14.9% and 27.1%, respectively. Additionally, the proposed occupant-in-loop analytical framework enables a comprehensive understanding of the interplay between occupants and environmental variables. This work advances indoor environment research by providing a robust and adaptable solution for predicting and analyzing indoor environmental dynamics.

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Gao, L., Li, D., Liang, N.

A hybrid sensor fault detection and diagnosis method for air-handling unit based on multivariate analysis merged with deep learning.

Advanced Engineering Informatics, Vol. **65**, (2025)

This paper proposes a novel air-handling unit (AHU) sensor fault detection and diagnosis (FDD) method by utilizing multivariate analysis merged with deep learning. In reality, sensor measurements in AHU systems are affected by outdoor air temperature, which results in poor detection performance of existing data-driven methods. To overcome this difficulty, a robust canonical correlation analysis (RCCA) is firstly proposed by removing the effect of outdoor air temperature, which is realized by performing an orthogonal decomposition of process variables. The better detection performance is delivered by using data from an orthogonal subspace of outdoor air temperature. Then, with the aid of the proposed detection method, a RCCA-based fault bank is constructed based on the principle of parity space. A neural network-based diagnosis method is proposed by means of the RCCA-based fault bank, which reduces the influence of noises and thus faults are easily diagnosed compared with traditional neural network-based methods. The proposed method is purely data-driven, and thus it is easily used for FDD in real systems. Finally, the effectiveness of the hybrid method is verified using experimental data from ASHRAE RP-1312. Results show that the proposed method is superior to the state-of-the-art methods, and the diagnosis performance is significantly improved by using the deep learning method with the aid of multivariate analysis.

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Zimmerman, J. H., Williams, A., Schumacher, B., Lutes, C., Warrier, R., Cosky, B.*, et al.*

Impact of Multiple HVAC Systems on Indoor Air VOC and Radon Concentrations from Vapor Intrusion During Seasonal Usage.

Atmosphere, Vol. **16** n°(4), (2025)

Subsurface contamination can migrate upward into overlying buildings, exposing the buildings' inhabitants to contaminants that can cause detrimental health effects. This phenomenon is known as vapor intrusion (VI). When evaluating a building for VI, one must understand that seasonal and short-term variability are significant factors in determining the reasonable maximum exposure (RME) to the occupants. RME is a semi-quantitative term that refers to the lower portion of the high end of the exposure distribution—conceptually, above the 90th percentile exposure but less than the 98th percentile exposure. Samples were collected between December 2020 and April 2022 at six non-residential commercial buildings in Fairbanks, Alaska. The types of samples collected included indoor air (IA); outdoor air; subslab soil gas; soil gas; indoor radon; differential pressure; indoor and outdoor temperature; heating, ventilation, and air conditioning (HVAC) parameters; and other environmental factors. The buildings in close proximity to the volatile organic compound (VOC) source/release points presented less variability in indoor air concentrations of trichloroethylene (TCE) and tetrachloroethylene (PCE) compared to the buildings farther down gradient in the contaminated groundwater plume. The VOC data pattern for the source area buildings shows an outdoor air temperature-dominated behavior for indoor air concentrations in the summer season. HVAC system operations had less influence on long-term indoor air concentration trends than environmental factors, which is supported by similar indoor air concentration patterns independent of location within the plume. The use of soil temperature and indoor/outdoor temperatures as indicators and tracers (I&Ts) across the plume as predictors of the sampling period could produce a good estimation of the RME for the building occupants. These results, which show the use of soil temperature and indoor/outdoor temperatures as I&Ts, will help advance investigative methods for evaluation of VI in similar settings and thereby improve the protection of human health in indoor environments.

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Cui, Y., Liu, X., Bai, L., Wang, X.

Improving fitness centre indoor environment comfort and health: A method for evaluating indoor environmental quality based on subjective and objective factors.

Indoor and Built Environment, (2025)

Compared to other indoor environments, indoor environments of fitness centre exhibit notable variations in heat, humidity and air quality. In this study, a 2-month field study was conducted on two fitness centres in a cold region of China. The results of this study revealed that fitness centres have high levels of indoor air pollutants, with significant variations in temperature and humidity. Moreover, the majority of individuals expressed dissatisfaction with the indoor environmental quality of fitness centres. The thermal comfort in fitness centres was closely associated with the ambient temperature and humidity. Amongst the pollutants affecting indoor air quality in fitness centres, carbon dioxide (CO2) was shown to produce the most significant impact, followed by formaldehyde (CH2O), total volatile organic compounds (TVOC) and particulate matter (PM2.5). In this study, a comprehensive evaluation model was developed to provide a reference for assessing the indoor environmental quality of fitness centres. The findings of this study can serve as a scientific foundation for the design and decoration of fitness centres, aiming to enhance the comfort and healthiness of the exercise environment.

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Furst, L., Cipoli, Y., Yubero, E., Galindo, N., Viegas, C., Dias, M.*, et al.*

Indoor air quality in a home improvement store: Gaseous pollutants, bioburden and particle-bound chemical constituents.

Building and Environment, Vol. **277**, (2025)

This paper provides a comprehensive assessment of indoor and outdoor air quality within a home improvement and gardening store chain in northeastern Portugal. In December 2021 and January 2022, two multipollutant systems were installed in the store and outdoors to assess air quality. Continuous monitoring included particulate matter below 10 µm (PM10), CO2 and comfort parameters. PM10 samples

were collected using gravimetric samplers during both occupied and vacant periods. These samples were then analysed for carbonaceous constituents and metal(loid)s. Additionally, volatile organic compounds (VOCs), carbonyls, bacteria, and fungi were passively sampled. Results showed higher indoor concentrations of PM10 during labour hours (45.4 ± 15.2 µg/m3), while outdoor values of 27.1 ± 9.96 µg/m3 were recorded. The elemental characterisation of PM10 revealed a high abundance of soil-related elements indoors, suggesting that resuspension is one of the primary sources. The most abundant elements were Ca, Fe, and Zn, with concentrations of 658 ± 297, 273 ± 141, and 172 ± 67.4 ng/m³, respectively. Outdoors, elements related to tyre and brake wear and road dust were predominant, indicating emissions from non-exhaust traffic emissions as the main source. A prevalence of α-pinene, limonene, and hexanal was found indoors, most likely related to wood products. Fungi with clinical relevance and toxigenic potential, and higher bacterial loads were observed in the gardening and heating sectors of the store. This study underscores the importance of investigating less-studied stores, as they may exhibit pollutant levels that exceed health protection thresholds.

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Altendorf, D., Berger, F., Dehnert, J., Duzynski, M., Grünewald, H., Trabitzsch, R.*, et al.*

Innovative Radon Mitigation: A Long-Term Study on the Effectiveness of Decentralised Ventilation with Heat Recovery.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

Radon-222 is a naturally occurring radioactive gas and a significant indoor air pollutant. Elevated indoor radon activity concentration significantly increases this risk of lung cancer for individuals. In accordance with the European Euratom Directive, the German government has established a reference value of 300 Bq/m³ as the annual mean for radon activity concentration in indoor workplaces and living spaces. Mitigating indoor radon is essential to ensure healthy living and working environments, particularly in areas with heightened radon exposure. This study presents the results of a three-year proof-of-concept investigation into the effectiveness of a decentralised ventilation system with heat recovery as a radon mitigation strategy.Therefore, a series of ventilation experiments were performed in an unoccupied ground-floor flat of a residential building in Aue-Bad Schlema, Germany. Located within one of Saxony’s radon-prone areas in the Ore Mountains (Erzgebirge), a region well-known for its numerous ore deposits and an 800-year long mining history. The flat was divided into three individually controllable ventilation zones using strategically positioned ventilation devices with heat recovery (inVENTer GmbH, Germany). These devices were controlled by a real-time measurement of indoor radon activity concentration (Smart Radon Sensors by SARAD GmbH, Germany), enabling dynamic and responsive operation of the ventilation system. By using the actual measured radon concentration [Rn] as a control parameter, the system can automatically switch between three distinct ventilation modes - "Heat Recovery", "Cross-Ventilation" and "Differential Pressure" - or deactivate entirely. Within each mode, both airflow direction and air volume flow rates can be adjusted, providing tailored solutions for effective radon mitigation.Overall, the decentralised ventilation system with heat recovery demonstrated significant potential for reducing indoor radon concentration, achieving reductions of up to 80 %. The effectiveness of the system varied based on factors such as initial room-specific radon levels, fan performance settings, and meteorological parameters like outdoor temperature and wind speed. The study also evaluated the dependencies between indoor radon levels and various environmental and site-specific factors. Results revealed that radon dynamics are influenced by a complex interplay of geological, meteorological and building-specific characteristics - including structural design and ventilation system configuration. Different ventilation modes, combined with varying fan performance levels, contributed to distinct radon reduction outcomes, highlighting the importance of customising mitigation strategies.These findings emphasize the necessity of integrating environmental and building-specific considerations into radon risk assessment and mitigation planning. Customised, site-specific radon mitigation strategies are essential to account for the variability introduced by local conditions, ultimately improving indoor air quality and reducing health risks in radon-affected regions.

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Luo, Q., Hang, J.

Inter-annual optimization of ventilation strategies in cruise ships: Integrating thermal comfort and infection risk mitigation across seasonal variations.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

<jats:p>Indoor ventilation optimization is important for air quality, thermal comfort, and airborne transmissions of infectious droplets, but research on cruise ships is scarce, especially across whole year seasons. How to weigh air quality and human comfort is an essential and practical issue. We utilize numerical simulations verified by field experiments to examine the thermal comfort and infection risk under natural ventilation and air-conditioning ventilation in various seasons. The scientific problem of this study is the proper utilization of natural and mechanical ventilation at the inter-annual scale to provide a good environment for passengers in the transportation environment. The effect of window opening configurations and ambient wind directions on natural ventilation has been explored. Varying filtration efficiencies are considered for air conditioners. The Monte Carlo method and dose-response model are adopted to quantify infection risk (IR). Results reveal that surrounding turbulent airflows create positive pressure on the windward side ship's surface and negative pressure on the leeward side. Compared to driving following wind and against the wind, the best ventilation in the cabin occurs during side wind, due to the large windward area with an air change rate per hour (ACH) above 61.78 h-1. In spring and fall, opening all side windows provides good thermal comfort (-1</jats:p>

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Romain, A.-C.

La qualité de l'air intérieur, un enjeu de santé et de conception pour le secteur de la construction : La qualité de l’air interieur, de quoi s’agit-il?

Conférence scientifique dans des universités ou centres de recherche Liège, Belgique

Anne-Claude Romain, Professeure à la Faculté des Sciences, responsable du Laboratoire SAM, ULiège, a démarré les échanges en posant quelques constats quant à l’impact avéré de l’intérieur du bâtiment sur le confort et la santé des occupants. Augmentation du syndrome des bâtiments malsains et des interventions des « Ambulances vertes », teneur en substances volatiles à l’intérieur supérieure à l’extérieur, charge de comorbidité liée à la qualité de l’air de 35%... Le premier état des lieux de la recherche dans le domaine de la qualité de l’air intérieur, en Europe, date de 2008. Cela est assez récent comparé à l’intérêt porté, depuis longtemps sur la qualité de l’air ambiant. Différentes études démontrant les impacts sanitaires de la qualité de l’air intérieur sur la santé ont ensuite été abordées, avec les symptômes observés. Le lien entre l’air intérieur et les préoccupations au sein des bâtiments a ensuite été fait. La performance énergétique (PEB), qui guide la conception des bâtiments en termes de réduction du coût énergétique et de la réduction des émissions de CO2 n’a pas que des avantages en termes de qualité de l’air intérieur car elle entraine, notamment, une augmentation du confinement (meilleure isolation thermique, diminution de l’aération et contrôle de celle-ci qui passe de « naturelle » à mécanique). Anne-Claude Romain a donc insisté sur le fait qu’un bâtiment certifié PEB n’est pas synonyme d’un bâtiment sain et que cette certification ne prend pas en compte l’impact sanitaire du bâtiment. Et de citer d’autre sortes de performance environnementale des bâtiments dont le Breeam (qui prend en compte différents critères comme l’énergie, la pollution, l’impact environnemental, la santé, le confort...). Les polluants de la qualité de l’air peuvent être chimiques, biologiques ou physiques. Les sources sont les échanges avec l’extérieur renouvellement d’air mécanique, infiltration naturelle, polluants extérieurs), les polluants issus du bâtiment lui-même (bâti et matériaux de construction, ameublement et décoration), l’occupation du bâtiment (interaction avec les surfaces, activités déployées...). Quant à la définition de la qualité de l’air intérieur, Anne-Claude Romain a expliqué qu’il n’y avait pas de consensus. Sur la composition et le CO2 non plus. La mesure de CO2 est souvent utilisée pour évaluer une bonne qualité de l’air intérieur, mais cette donnée n’est pas correctement interprétée. Il s’agit en effet d’un indicateur de ventilation et de présence humaine et non d’un indicateur de la qualité de l’air intérieur (cf. position document de l’ASHRA qui propose une synthèse sur l’utilité du CO2 comme critère). Pour améliorer la qualité de l’air intérieur il faut bien sûr pouvoir la mesurer. Pour évaluer la pollution intérieure, il existe deux approches : dans le bâtiment/habitation (analyses sur place et ou échantillons en laboratoire par le Service d’Analyse des Milieux Intérieurs...) et en laboratoire, dans des

chambres d'émission (test des matériaux et produits). Enfin, la chercheuse a brossé la réglementation en la matière qui diffère entre la Wallonie, la Flandre, le Fédéral, et les pays européens. Et de souligner un manque d'harmonisation.

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Xu, K., Li, K., Shi, Y., Ding, R., Liu, Y., Shi, Y.*, et al.*

Melamine derivatives in indoor dust from China: Temporal trends and human exposure before and during COVID-19 pandemic.

Journal of Hazardous Materials, Vol. **494**, (2025)

Melamine-based compounds (MELs) are emerging indoor contaminants with potential health risks, yet their temporal variations and exposure implications remain poorly characterized. In this study, we analyzed MELs in 66 paired indoor dust samples from residential households in Tianjin, China, comparing pre- and during-COVID-19 periods. Four traditional MELs, i.e., MEL, ammeline, ammelide, and cyanuric acid (CYA), were detected in all samples, with total MEL concentrations (∑MELs) ranging from 61.2 to 5.83 × 104 ng/g (median: 6.73 ×103 ng/g). During the pandemic, ∑MEL concentrations increased 1.73-fold (8.25 ×103 vs. 4.76 ×103 ng/g, p < 0.01), with CYA emerging as the predominant compound (median: 2.82 ×103 ng/g), likely due to its extensive use in disinfectants (up to 0.4 % and 20 % in liquid and tablet formulations, respectively). Human exposure assessment revealed that infants had the highest estimated daily intakes (EDIs, 40.1–69.6 ng/kg bw/day), about an order of magnitude higher than adults (3.31–5.74 ng/kg bw/day), primarily through dust ingestion. Non-carcinogenic risks (HQs<1) and lifetime cancer risks (maximum median from teenagers: 7.98 ×10−8) remained within negligible limits. Monte Carlo simulations identified indoor dust concentration and body weight as key risk determinants. These findings underscore the environmental consequences of pandemic-driven disinfection practices and the urgent need for regulatory oversight of MEL-containing materials.

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Xu, K., Wu, K., Xu, J., Planche, M.-P., Deng, S., Liao, H.*, et al.*

Metal oxide semiconductor-based heterojunctions synthesized by wet-chemical strategies for efficient volatile organic compounds detection.

Coordination Chemistry Reviews, Vol. **538**, (2025)

Metal oxide semiconductor (MOS)-based chemiresistive sensors have been widely applied in indoor air quality detection, medical diagnostics, and environmental monitoring, and they also hold promise for future applications in agricultural product quality assessment. Developing sensitive materials with enhanced stability, humidity resistance, and high selectivity toward specific gases has become a key focus for their application in complex environments. Among these efforts, the construction of optimized heterostructures has gained significant attention and seen substantial progress in recent years, driven by advancements in material characterization techniques, electrochemical research, and the growing use of Density Functional Theory (DFT) calculations. Nevertheless, few reviews offer a comprehensive overview of heterostructure types and a clear explanation of their wet-chemical synthesis principles and sensitization mechanisms. Reviewing research papers published between 2020 and 2025, this work focuses on MOS-based composite materials constructed by various wet-chemical technologies for monitoring volatile organic compounds (VOCs). It categorizes three representative types of heterostructures—uniform distribution type, surface-loaded type, and core-shell type—based on the distribution of the second phases. It offers a comprehensive analysis and summary of the construction strategies for each configuration, the charge exchange between materials and gas molecules, electron transport within and between materials, and potential sensitization effects. On this basis, a comparative analysis identifies the key points for designing each configuration, the gaps in current research and achievements, and the potential focus for future investigation. This review aims to provide guidance for synthesizing highly efficient sensitized heterostructure materials.

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Mesburis, R., Rutherford, M., Handschy, A. V., Day, D. A., Morris, M. A., Ziola, A. C., *et al.*

Mitigation of indoor air pollution from air cleaners using a catalyst.

ChemRxiv, (2025)

The COVID-19 pandemic highlighted the importance of indoor air quality and the role of airborne transmission in disease spread. Heightened public awareness led to an increase in the commercialization and use of air cleaners. While several of these devices effectively disinfect the air, some also initiate chemical reactions that can worsen indoor air quality by generating ozone (O3) and other harmful air pollutants. Here we demonstrate the use of a catalyst to mitigate both air cleaner-generated and ambient pollution in a real indoor environment. We deployed two real-time chemical ionization mass spectrometers alongside a suite of air quality analyzers to measure a wide range of volatile organic compounds (VOCs), other trace gases, and particles. We show the reduction of many indoor pollutants, including O3, nitrogen oxides, formaldehyde, and other oxidized VOCs. We observe an increase in the concentrations of more reduced VOCs with catalyst use. We demonstrate that over 16 weeks of continuous operation, the clean air delivery rate of the catalyst for O3 pollution declined linearly by 12.5%. These findings suggest that employing a dedicated catalyst could reduce indoor air pollution and enhance the human health benefits of air cleaners by minimizing the associated indoor air quality risks.

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Hussain, K., Bashir, M. H., Ahmad, H. R., Shehzad, M. T., Zulfqar, A.

Modeling source identification of dust and paint metals effecting workshops indoor air quality: associated contamination and cancer risk.

Modeling Earth Systems and Environment, Vol. **11** n°(3), (2025)

The automobile industry in Pakistan is affected by economic crises, leading to a surge in old vehicle imports. This study assessed exposure to cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni) in paints and dust samples from auto workshops. A total of 56 samples of four dust and paint flakes from each of the 14 workshops were collected based on high traffic, long operational history, and dense population areas in Faisalabad. Heavy metal concentrations were analyzed using an atomic absorption spectrophotometer. Results revealed that the maximum concentrations in dust samples were 3.11, 78, 46, and 31 mg kg−1 for Cd, Cr, Pb, and Ni, respectively, while in paint samples, they were 10, 7.4, 93, and 18 mg kg−1. Positive matrix factorization (PMF) model attributed metal sources to human activity and corrosion of aged vehicular components. The geo-accumulation index was maximum for Pb at W13, Cd and Cr at W10, and Ni at W9 while the Cr, Pb, and Ni had moderate contamination factors (CF), whereas Cd had CF of high pollution. Workshops W11 and W14 recorded pollution load index > 1, showing contamination. Ecological risk was low, with the exceptions of W2 and W12 (moderate risk), and potential ecological risk was high. For adults and kids, the total cancer risk (TCR < 1) and non-carcinogenic health hazard (HI < 1) were low. The study recommends implementing regulations to control risks and training workers to reduce exposure to contaminated dust and paints.

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Hajatia, M., Ghorbanib, B.

Numerical simulations of the airflows in a room: Prediction of the mean age of air (MAA).

AirDummies 2025

This paper presents the results of a numerical study on airflow modeling in a room with mixing ventilation. Results which are based on the mean age of air (MMA) are validated against existing experimental works in the literature. The numerical results were obtained by performing CFD analysis using the AirDummies software while the tracer gas concentration decay method is employed for experimental measurements. k-ω SST turbulence model is used along with proper boundary conditions to find the velocity field and MMA. The inlet velocity of 1.68 m/s and air changes per hour (ACH) of 8 were set with Schmidt number of 2 for

MMA diffusion modeling. The room modeled was 4.2 m long, 3.6 m wide, and 3 m high which is exactly similar to the dimensions used in the experimental work. The MMA was calculated at different heights at the distance of 1.13 m, 2.2 m, 3.2 m from the west-facing wall. It is shown that AirDummies provides pretty much the same results as the experimental work.

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Peng, G., Mikko Poikkimäki, M., Leppänen, M., Kanerva, T., Materić, D., Reemtsma, T.

Occupational Exposure to Elevated Levels of Inhalable Microplastics in Plastic and Fiber Factory Workers.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

Micro(nano)plastics enter the human body mainly through inhalable and oral uptake, and the fraction below 20 µm can penetrate biological membranes, accumulate in tissues, and induce cytotoxicity and inflammation. While inhaled indoor air may be a primary source of exposure, concentrations are potentially higher in occupational settings in the plastic and fiber factories. Here, external exposure to inhalable microplastics <100 µm was studied in four industrial workplaces: two non-woven fabric production factories, and two different plastics recycling facilities located in Finland and Spain. Air samples were collected from the worker breathing zone and stationary measurements during various production tasks. For comparison, urban aerosols were assessed in two urban locations in Finland and in France. Inhalable microplastics in the aerosol samples were analyzed using FTIR (Fourier-transform infrared microscopy) imaging and Raman spectroscopy equipped with automated particle analysis and identification algorithms. In addition, total particle number concentration (PNC, 20 – 700 nm) were measured in parallel. PNC varied between the workplaces and tasks, ranging from 2000 to 50000 #/cm3. Aerosols in the plastic recycling factory predominantly contained PS, ABS, PP, PE and EVA particles at elevated concentration, averaging 2000 #/m3 for the inhalable fraction (<100 µm) and 1500 #/m3 for the thoracic and respirable fraction (<10 µm), based on FTIR imaging and Raman analyses. In non-woven fabric manufacturing facilities, inhalable microplastics were dominated by PET fibers, along with PA, PP and PE particles. The median size of inhalable microplastics ranged from 23 – 40 µm in occupational aerosols. Inhalable microplastics in aerosols from the 4 factories ranked among the highest concentrations reported to date, indicating elevated health risks for exposed workers. These novel findings from the validation of sampling and analytical strategies underscore the significance in reducing airborne microplastic emissions and mitigating inhalation exposure, especially in occupational settings.

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Salamalikis, V., Hasani, A., Castell, N., Kephalopoulos, S., González, Ó., Nenes, T.*, et al.*

Opportunities and challenges of sensor technology for indoor air quality monitoring.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

<jats:p>Indoor air quality (IAQ) plays a vital role in providing healthier indoor environments, especially considering that most human activities occur indoors. Since indoor and outdoor air pollutants are closely interrelated, monitoring both can provide insights into IAQ dynamics.   The IDEAL (Indoor Air Quality Health) Cluster comprises seven Horizon-Europe funded projects (InChildHealth, INQUIRE, LEARN, K-HealthinAIR, SynAir-G, TWINAIR, and EDIAQI) and the Working Group (WG) on Sensors aims to enhance understanding of knowledge gaps in IAQ, identifying IAQ determinants and to assess their health impacts using various sensor technologies. The goal of the WG on Sensors is to develop common documentation on sensor types, operation modes, characterization, calibration, performance, assessment and validation methods for indoor air quality monitoring and health impact assessment.   The documentation is informed by the different technologies and methodologies used across the seven EU-projects. We have found that the most commonly measured parameters include particulate matter, total volatile organic compounds (TVOC), CO2 and comfort parameters (temperature and relative humidity) although other parameters are also monitored based on the specific needs of each project. Low-cost sensors for

indoor air quality monitoring are used across all the IDEAL cluster’s projects, although they come from different manufacturers. For example, VOCs are monitored using metal oxide sensors from Sensirion, Alphasense, and Figaro, with non-distinction of the VOC species to be the common challenge across all low-cost sensors. All the projects have planned for co-location to understand the data quality. Sensor-measured particulate matter is mainly validated against reference measurements in the field, and in two out of seven projects co-location campaigns conducted in various European countries to assess how the sensors respond in different indoor environments. In this transfer learning approach, all projects share their experiences, highlighting the advantages, limitations, and challenges associated with using different sensor technologies to measure air pollutants. All information gathered is mapped to identify possible similarities and challenges in measuring common parameters across the seven IDEAL Cluster’s projects. This information can be proven useful also to projects pertaining to other citizen science initiatives that are interested in monitoring IAQ.   Acknowledgments: We acknowledge funding for INQUIRE project from the European Union’s Horizon Europe Research and Innovation programme under grant agreement No.1011057499. </jats:p>

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Ma'bdeh, S. N., Alali, R. O., Al-Shawabkeh, M., Almomani, R. M., Hamasha, A. A., Shannik, R.*, et al.*

Optimizing airflow in double-skin facades: Influence of vents design and cavity depth.

Cleaner Engineering and Technology, Vol. **26**, (2025)

Despite the energy-saving potential of NVDSFs, this research examined the effectiveness of the Double-Skin Facade (DSF) system by optimizing its geometric configurations to enhance natural ventilation and indoor air quality in office buildings. Using Butterfly plugin inside grasshopper software, compared the performance of the DSF system to a base case without DSF in Amman, Jordan. The proposed scenarios demonstrated improvements in indoor air quality, increasing the actual-to-required ventilation ratio to 5.3, compared to 3.75 in the base case, according to American Society of Heating, Refrigerating, and Air-Conditioning Engineers) (ASHRAE 62) standards. Furthermore, identified locations with the lowest velocities and analyzed high-turbulence areas to optimize space use. The most important qualitative results were found that room corners, particularly near the inlet and outlet proposed openings, were found to be a high turbulence and were less acceptable to users.

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Teh, K. J. L., Razali, H., Lim, C. H.

Performance on Thermal Comfort and Indoor Air Quality: A Case Study of a Hypermarket in Tropical Climate.

Preprints, (2025)

his study assesses thermal comfort and indoor air quality (IAQ) across different zones within a hypermarket located in Gombak, Selangor, Malaysia, a region characterized by a tropical climate with high humidity and temperature. Key indicators, including Predicted Mean Vote (PMV), Percentage of People Dissatisfied (PPD), and IAQ parameters such as carbon dioxide (CO2), total volatile organic compounds (TVOC), PM2.5, and PM10, were evaluated. Significant disparities were observed between zones, with the cafeteria (Zone 5) recording the highest discomfort levels, marked by a PPD of 50%, CO2 concentrations of 900 ppm, and TVOC levels reaching 1500 ppb, primarily due to cooking activities and inadequate ventilation. In contrast, the intermediate retail zone (Zone 3) demonstrated favourable conditions, with a PPD of 12% and PMV values within the recommended range. These findings were benchmarked against ASHRAE 55 and Köppen-Geiger climate classification standards, emphasising the need for targeted improvements to enhance the thermal comfort and IAQ of the hypermarket indoor environment.

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Ndou, M., Aigbavboa, C., Thwala, W., Mahamadu, A.-M.

The Phenomenon of Indoor Air Quality.

In. Routledge; 2025. 41-90 p.

The theoretical foundations and definition of indoor air quality within the setting of the study, as well as the footprints that it leaves behind, are imperative in achieving the aim of the study. In order to develop the core theoretical perspective on which the study is constructed, a survey of previous and current literature is conducted from both a theoretical and conceptual perspective. The chapter gives further insight into the growth of indoor air quality in higher education, as well as its footprints in sustainability, economic developments and technology advancements, among other initiatives. In addition, the factors that influence the quality of the air inside municipal buildings, as well as the steps that may be taken to reduce the impact of these elements, are also examined. Afterwards, the lessons that were gathered from the review of

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Zuo, X., Yao, Q., Li, C., Zhao, Y., Hu, J., Li, L.*, et al.*

Research and Analysis of Active Purification and Fragrance Systems for In-vehicle Environment.

E3S Web Conf., Vol. **625**, (2025)

With the intensification of volatile organic compounds (VOCs), fine particulate matter (PM2.5), and microbial pollution in passenger vehicles, indoor air quality has become a crucial factor affecting the health and experience of drivers and passengers. This study reveals the interactive mechanism between technological performance and user experience through a comparative analysis of the synergistic effects of active air purification technologies and in-car fragrance systems, combined with empirical research on 17 automotive companies. The research indicates that mainstream automakers are optimizing purification efficiency and fragrance release strategies to meet consumers' dual demands for health protection and sensory comfort. This article provides a theoretical framework and practical guidance for the iteration and market application of related technologies in the automotive industry.

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Gan, D., Pan, J., Xu, J., Li, R., Luo, Y., Zhou, X. A.

Research on the Influence of Window Structure on Indoor Ventilation Based on CFD.

6th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2024)

Indoor air circulation is significant in maintaining indoor air quality and comfort. As one of the main channels for indoor and outdoor air exchange, the design of window structure is essential for indoor air circulation. Based on the simulations of three window structures using ANSYS Fluent software using computational fluid dynamics (CFD) method, this study aims to investigate the effects of different window structures on indoor air circulation. The results show that left-right sliding window and push-pull rotating composite window performed well in improving indoor air circulation. These findings can provide a basis for the selection of architectural windows and provide a reference for the optimization of window structures.

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Amer Syazwan, I., Allan Melvin, A., Irdina Faqilah Mohd, Z., Aimi Salihah Abdul, N., Wan Azani, M., Erdy Sulino Muslim, T.*, et al.*

A Review of Existing Method, Research and Emerging Technologies in Particulate Matter Evaluation Field.

Journal of Advanced Research in Applied Sciences and Engineering Technology, Vol. **64** n°(2), (2025), 130-140 p.

<p>Health effects and quality of life can be adversely affected by air pollution. Particulate Matters (PM) are one of the noxious substances caused by atmospheric pollution. Generally, in air quality index (AQI) calculation, most atmospheric monitoring devices does not evaluate particulate matter 0.1 micron, also known as ultrafine particles (UFP), due to the difficulty in evaluating particles of such small size, resulting in

inaccurate air quality index calculations. Most of the current detection and evaluation techniques, such as Gravimetric, Optical, Microbalance have reliability issues and limitations to be implement in monitoring field. In addition to being expensive, existing methods to detect PM are not geared toward air quality monitoring especially UFPs evaluation. The purpose of this article is to review existing method and summarize recent technological advancements in particulate matter detection methods. In addition, this paper explores latest progress and development in evaluating particulate matter. In this review, the researcher will gain insight into the advancement and challenges of particulate matter detection technologies.</p>

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Ramya, M. R., Sharavan, M. S. A., Taj, M. S. A., Kaviyarasan, M. D.

Smart Air and Water Quality Monitoring for Industrial Emissions using IoT and Machine Learning.

2025 International Conference on Machine Learning and Autonomous Systems (ICMLAS). 10-12 March 2025. Prawet, Thailand

The system is an integrated and intelligent solution for the tracking and quality management of air and water in industrial environments. As the system utilizes sophisticated sensors of the IoT that can measure key parameters like Total Dissolved Solids, pH, turbidity, dissolved oxygen, temperature, NH3 levels, heavy metals, and harmful gases, it feeds in data at continuous, real-time sites to operators and regulatory bodies. Access and visualization of monitored data can be done through ThingSpeak and the data is stored in google firebase, letting in proactive response and decision-making about keeping emissions and pollutants within legal standards. The dataset can be used for applying machine learning techniques like Random Forest combined with gradient boosting to predict the future pollution levels.

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Talati, I., Shah, K., Patel, O., Tanna, I., Iain, A., Oza, A. D.*, et al.*

Study of AQI Monitoring System of Indoor Environment Using Machine Learning Model and IoT Device.

ROCZNIK OCHRONA SRODOWISKA, Vol. **27**, (2025), 152-163 p.

ndoor air quality has a direct impact on human health. Thus, it's essential to comprehend the various aspects of indoor air quality. It supports both the implementation of preventative measures and the monitoring of indoor air pollution. Monitoring and forecasting air pollution is extremely essential, especially in developing countries like India. This study proposes a system that employs ESP8266 (NodeMCU) data sent to the cloud to monitor the levels of air pollutants such as ozone, particle matter, carbon monoxide, carbon dioxide, temperature, and total volatile organic compounds. Our sensors include the ozone sensor MQ-131, the dust sensor GP2Y1010-AU0F, the TVOC sensor AGS02MA, the carbon monoxide sensor MQ-9, the carbon dioxide sensor MQ-135, and the humidity sensor DHT11. The IoT device continuously shows the indoor air quality level (IAQL). The next step was to accurately anticipate the Internal Air Quality Level (IAQL) and pollution levels from dangerous gases for the next seven days using the LSTM, Seasonal ARIMA, and Linear Regression models. The Authors could accurately predict the observations of the following seven days after using data from the previous ninety days to create our best model. This implies that our model can accurately predict the values for each parameter with an accuracy of at least 95%. Therefore, we believe such a solution would be advantageous if a large-scale installation were implemented. If consumers can remotely verify the air quality in their homes, the pollution in the interior atmosphere will decrease. This has the potential to make civilization healthier.

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Soleimani-Alyar, S., Soleimani-Alyar, M., Yarahmadi, R., Beyk-Mohammadloo, P., Fazeli, P.

The study of indoor particulate matter in office buildings based on artificial intelligence.

International Journal of Environmental Science and Technology, Vol. **22** n°(7), (2025), 5763-5776 p.

The necessity of supplying proper indoor air quality in workplaces to provide the principles of a healthy and productive labor force and avoid negative outcomes is a known fact. This study assessed particulate matter (PM) concentrations in office buildings of governmental organizations across five regions in Tehran over four seasons (2018–2019) to model annual indoor PM patterns using machine learning. PM concentrations, including PM1, PM2.5, PM10, and Total Particulate Matter (TPM), were categorized using ensemble modeling techniques such as Linear Regression, Random Forest, Gradient Boosting, XGBoost, CatBoost, Support Vector Regression, and K-nearest neighbors. Key air quality parameters measured were CO2 (784 ppm), SO2 (0.114 µg/m3), PM2.5 (4.604 µg/m3), temperature (24.8 °C), and relative humidity (21.16%). While most parameters met guidelines, PM10 levels (97.5 µg/m3) exceeded WHO standards and relative humidity was below recommended levels, highlighting areas for improvement. PM2.5 and PM10 showed the strongest positive correlation (p value = 0.0001) and similar seasonal trends, with higher concentrations in autumn and summer and lower levels in spring and winter. The southern region exhibited consistently higher PM concentrations, while no significant changes were noted in the East or West. Among the models, CatBoost performed best in predicting air quality. The study suggests that indoor PM levels are influenced by psychrometric conditions and building location, providing valuable insights for improving air quality and occupant health.

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Yudhi, F., Alhamid, M. I., Putra, N., Lubis, A.

A study on temperature, relative humidity, and energy consumption in long-distance trains air conditioning systems in Indonesia.

Case Studies in Thermal Engineering, Vol. **71**, (2025)

Trains are efficient and cost-effective means of public transportation capable of carrying large groups of passengers. The Heating, Ventilation, and Air Conditioning (HVAC) system, a significant component with substantial energy usage in train operations, often encounters issues due to problems with the HVAC system failing to provide comfortable air quality, ultimately impacting passenger satisfaction and posing concerns for operators. A significant disparity in understanding of HVAC systems on Indonesian trains is frequently observed in tropical regions, where ensuring good air quality, stable temperatures, and controlled relative humidity levels over extended periods poses unique challenges due to the typically hot and humid climate characterized by high external temperatures and fluctuating humidity levels. Therefore, this study aimed to evaluate the ability of HVAC systems to maintain temperature and humidity in trains. Temperature and humidity were measured during the journey at various areas in passenger compartments in three executive class intercity trains, covering both day and night conditions. The results showed that maintaining a consistent level of thermal comfort parameters throughout the journey was challenging for HVAC systems. Data suggests that temperature fluctuations took place during the daytime, whereas relative humidity (R.H) levels in the night and early morning rose to 28.2 °C and 81.2 % respectively, surpassing the established standards ISO 19659–2 of 27 °C for temperature and 65 % percent for relative humidity. These results were expected to guide the improvement of future HVAC systems designs, enhancing their ability to maintain consistent temperature under varying conditions. Additionally, the designs would focus on better humidity control through the incorporation of a reheating process in air supply, ensuring consistency of long-distance journey.

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Dutta, S., Bansal, P.

Sustainability aspect of wearable clean room filters: a review.

Polymer Bulletin, (2025)

In sectors such as pharmaceuticals, microelectronics, biotechnology, and healthcare, clean room filters are essential to upholding strict air quality standards. In order to provide a regulated atmosphere necessary for high-precision manufacturing and research, these filters are made to capture airborne pollutants such as particles, bacteria, and chemical vapors. The functionality of clean room filters is examined in this paper,

with particular attention paid to new developments, material composition, filtration processes, and efficiency. Ultra-low penetration air (ULPA) and high-efficiency particulate air (HEPA) filters continue to be the industry standard, using electret-based improvements and fibrous media to achieve greater performance. Important functional characteristics are looked at, including durability, airflow resistance, particle collection efficiency, and resistance to microbiological contamination. It also emphasizes the use of sustainable substitutes, such as biodegradable and energy-efficient filtration media, as well as nanofiber-based filters. There is also discussion of new developments in smart filtration technology that use sensors and real-time monitoring systems. The assessment emphasizes how clean room filtration requires constant innovation to improve performance and solve environmental issues. Next-generation clean room filters can achieve greater efficiency, longer operational lifespans, and less environmental impact by combining innovative materials and automated monitoring. This study helps to shape future research and industry applications by offering insights into the changing field of clean room filtration.

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Garcia-Vilchez, M., Torres, P., Raush, G., Castilla, R., Gelmá, M. T., Morte, M.

Towards a Simplified Numerical Methodology for Estimating the Efficiency of an Air Handling Unit.

Preprints, (2025)

This work presents a study on the calculation of transmittance in an Air Handling Unit (AHU) through three methods: theoretical estimation, experimental approach and numerical simulations. First, a theoretical estimation based on simplified models of heat and mass transfer in the AHU was employed. In addition, experimental tests were carried out in a real AHU under controlled conditions, obtaining temperature measurements inside and outside the unit. These data were used to calculate the transmittance using predefined formulas. Finally, numerical simulations were performed on specific sections of the AHU and on a global model, with and without radiation considering its influence. The simulations provided detailed results on the flow behaviour and temperature distribution. The results obtained were compared and analysed to assess the accuracy and applicability of the three methods. This research contributes to the knowledge and understanding of transmittance in AHUs, providing valuable information for the design and optimisation of Heating, Ventilation, and Air Conditioning (HVAC) systems.

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González-Gómez, M., Benito-Altamirano, I., Prades, J. D., Casals, O., Fabrega, C.

Ultra Low-Cost and Selective Water-Based Colorimetric Ink for Indoor CO2 Monitoring.

IEEE Sensors Journal, (2025)

This work introduces a novel water-based colorimetric ink for CO2 monitoring, offering a significant advancement in indoor air quality assessment. The ink uses a highly specific and reversible reaction between CO2 and an amine, enabling precise detection within a broad operational range of 150-1500 ppm, encompassing typical indoor CO2 concentrations. Optimized rheological properties allow for seamless application on paper substrates, facilitating scalable production and widespread adoption. The resulting colorimetric labels exhibit exceptional resistance to common interfering gases, ensuring accurate and reliable CO2 readings even in challenging indoor environments with fluctuating humidity and temperature and potential cross-contamination. Rigorous characterization of the sensor showcases outstanding performance in terms of specificity, repeatability, and reproducibility, validating its robustness and suitability for real-world applications. To further enhance accuracy, a calibration methodology incorporating a signal compensation algorithm is proposed, effectively mitigating humidity-induced effects. The sensor response can be effortlessly captured using readily available and cost-effective electronic components, paving the way for an accessible and versatile solution for real-time CO2 monitoring in both residential and commercial settings. Moreover, the inherent versatility of this technology allows for integration with other colorimetric inks, opening doors to a multi-parametric sensing platform capable of monitoring a wider array of indoor air quality pollutants.

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Mangin, T., Barrett, Z., Palmer, Z., Tang, D., Nielson, S., Sleeth, D.*, et al.*

Understanding the effect of outdoor pollution episodes and HVAC type on indoor air quality.

Building and Environment, Vol. **278**, (2025)

This study evaluated the impact of poor outdoor air quality on indoor air quality over 18 months using 21 low-cost PM2.5 sensors (at 17 indoor and two outdoor locations) with a focus on inversion, dust, and wildfire smoke events. In addition to the impact of outdoor air quality on indoor air quality, this study evaluated how different heating, ventilation, and air conditioning (HVAC) systems affect the infiltration of outdoor PM2.5 in commercial buildings. Wildfire smoke events had the largest impact on indoor air quality. Infiltration factors averaged over all locations for inversion, dust, and wildfire smoke events were 0.07, 0.10, and 0.37, respectively. Additionally, HVAC systems equipped with an air-side economizer showed higher PM2.5 infiltration factors compared to other systems regardless of pollution event.

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Thompson, R., Fisher, S., Ierardi, A. M., Pavilonis, B.

Validating low-cost indoor air quality monitors to improve exposure monitoring in nail salons.

EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025

In the US, approximately 200,000 nail salon workers face chronic exposure to airborne chemicals. Health effects among this sector have been well documented and public health laws aimed at exposure reduction have been implemented across the US. In this study, we evaluated the accuracy and feasibility of using commercially available low-cost sensors as tools for workers to monitor and reduce their daily exposures. We compared the performance and utility of six commercially available low-cost total volatile organic compound (TVOC) sensors (Awair Omni, Kaiterra Sensedge, UHoo Smart Air Monitor, Airthings View Plus, Atmotube, and Atmocube) to validated reference instruments. Sensors were collocated in at least 4 different salons for 7 consecutive days during an initial baseline measurement period. Salons then received an intervention on methods to reduce exposure by utilizing existing controls and another 7 days of exposure measurements were collected. TVOC measurements from low-cost sensors exhibited moderate to strong correlations (rs ~ 0.54 - 0.88) with readings from validated reference instruments. Accuracy of the low-cost sensors varied, especially at higher TVOC concentrations and after repeated days of use. Low-cost sensors on average underestimated TVOC concentrations at the highest quartile of exposure (Mean Absolute Error (MAE) Q4: 16.19 – 28.49 ppm) but performed more similarly to reference instruments at lower quartiles of exposure (MAE Q1: 0.69 – 2.53 ppm, Q2: 1.60 – 2.75 ppm, Q3: 5.55 – 6.85 ppm). Despite some limitations, these sensors can be valuable tools for exposure assessment, including monitoring nail salon workers' daily exposures and studying the health effects of chemical exposures in longitudinal epidemiologic studies among this group.

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Ghorbani, B., Hajati, M., Rahnama, A.

Validating of AF-3623VT Modeling with AirDummies: A Comparative Analysis against Experimental Data.

AirDummies 2025

This study examines the modeling of the AF-3623VT air purifier using AirDummies software. The primary objective is to validate the modeling results against experimental data from Tanis Technologies[1] and NASA[2]. The findings reveal a strong alignment between the AirDummies' prediction and experimental data, demonstrating the reliability of the simulation for predicting air purification performance. This validation is crucial for enhancing the design and effectiveness of air purification systems. Following the validation, the study presents a detailed demonstration of the AF-3623VT's purification performance with a single contamination source in the room, highlighting its practical applications in real-world settings.

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Ghorbani, V., Tariq, S., Yoo, C.

Validation of Subway Indoor Air Quality (IAQ) Data Using Memory-Augmented Autoencoders with Learned Normal Prototypes.

Korean Journal of Chemical Engineering, (2025)

Indoor air quality (IAQ) monitoring in subway stations depends on sensors prone to failures due to confined spaces, cyberattacks, and prolonged use. Soft sensor validation frameworks using statistical or machine learning models can detect, diagnose, and reconstruct faulty data but struggle with complex fault patterns. This study introduces a memory-augmented autoencoder-based framework for reliable IAQ sensor validation, leveraging memorized normal prototypes. To the best of our knowledge, this is the first validation method that utilizes normal prototypes for reconciling corrupted measurements. Tested on real IAQ data from Seoul Metro's C-station, the method achieved a 97.03% detection rate, a 4.33% false alarm rate, and demonstrated potential for 10.25% energy savings while maintaining healthy IAQ.

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Hennies, P., Bertram, E., Stergiaropoulos, K.

Ventilation Effectiveness: Overview of Terminology and Analysis of Influencing Parameters.

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

Ventilation effectiveness evaluates the performance of ventilation systems by assessing air exchange and contaminant removal. Optimising ventilation effectiveness in mechanical ventilation systems reduces the required supply airflow rate while maintaining adequate indoor air quality. This review clarifies inconsistent definitions of ventilation effectiveness in standards and literature and provides a comprehensive overview of terms, definitions, and relevant parameters. The review also analyses the influence of variable and building-fixed parameters on ventilation effectiveness using data from selected studies. Contaminant position and supply/exhaust position had the greatest impact on ventilation effectiveness, with maximum absolute changes of 2.1 and 0.94, respectively. Variable parameters, such as air change rate and temperature difference, showed moderate mean absolute changes of 0.28 and 0.15 but significant maximum deviations of 0.85 and 0.4. Building-fixed parameters, including room size and aspect ratio, showed the least influence, with mean absolute changes below 0.1. These results highlight the importance of parameter interactions, such as short-circuit flows caused by higher air velocities. In EN 16798-1:2022, design values for required airflow are based on a ventilation effectiveness of 1. However, the analysis shows large variations around this value, indicating potential deficits in air quality and opportunities for energy savings. This review highlights the need for holistic system design and consideration of parameter interactions to optimise energy efficiency and air quality.

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Horvat, T., Pehnec, G., Jakovljević, I.

Volatile Organic Compounds in Indoor Air: Sampling, Determination, Sources, Health Risk, and Regulatory Insights.

Toxics, Vol. **13** n°(5), (2025)

Indoor air pollution is a serious public health issue caused by the accumulation of numerous toxic contaminants within enclosed spaces. Particulate matter (PM2.5 and PM10), biological contaminants (mould, bacteria, and allergies), inorganic gases (carbon monoxide, carbon dioxide, ozone, and nitrogen dioxide), and a variety of volatile organic compounds (VOCs) are examples of common indoor air pollutants. VOCs are one of the chief indoor contaminants, and their effects on human health have made indoor air quality a serious concern. Indoor VOC concentrations are frequently higher than outdoor levels, according to studies, which raises the danger of exposure, particularly for young people and those with respiratory disorders. VOCs originate from both biogenic and anthropogenic sources, and they can create

secondary pollutants like ozone and aerosols, which can lead to cardiovascular and pulmonary problems. Prolonged exposure to VOCs has been associated with respiratory irritation, neurological effects, and an increased risk of chronic diseases. This review examines the primary sources, sampling and analysis approach, and health impact of VOCs in indoor air. Additionally, we compared worldwide regulatory guidelines for VOC exposure limits, emphasizing the need for strict exposure limits to protect human health.

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Liao, C., Miyata, S., Qu, M., Akashi, Y.

Year-round operational optimization of HVAC systems using hierarchical deep reinforcement learning for enhancing indoor air quality and reducing energy consumption.

Applied Energy, Vol. **390**, (2025)

Balancing user comfort demands with energy consumption in heating, ventilation, and air conditioning (HVAC) systems is a critical challenge in the field of control optimization. Currently, deep reinforcement learning (DRL) algorithms have achieved some success in optimizing HVAC system control. However, training agents with existing algorithms becomes challenging, when dealing with the hybrid action control problem. This study proposes an HVAC system optimization control method based on hierarchical deep reinforcement learning (HDRL), which aims to minimize system energy consumption while ensuring indoor comfort and maintaining air quality. The proposed HDRL method employs a two-layer agent architecture, where the bottom agent is responsible for optimizing the frequency control of fans and pumps and the top agent flexibly selects the daily operating mode based on outdoor meteorological conditions. We designed a multi-objective reward function based on Gaussian distribution, hyperbolic tangent function, energy consumption normalization for bottom agents, and temperature-based reward function for the top agent to achieve the reliable training of the agents. Experimental results indicated that the HDRL method significantly improves indoor temperature and CO2 concentration control during the year-round operation of the HVAC system. Compared to conventional PI control, the temperature compliance rate is increased by 8.37 %, and the combined temperature and CO2 compliance rate is improved by 7.8 %, while achieving a 3.95 % reduction in energy consumption.

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