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

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Google Scholar, Lens, WoS

Eklund, B., Plantz, G., Regan, C.

1,2-Dichloroethane in Indoor Air.

Remediation Journal, Vol. **35** n°(3), (2025)

ABSTRACT 1,2-Dichloroethane is a manmade compound used in the production of vinyl chloride. Due to its toxicity, it generally has relatively low screening levels based on acceptable concentrations in indoor air, soil vapor, and groundwater. If a release of 1,2-dichloroethane has occurred, the compound may be detected in the subsurface and could be a risk driver for vapor intrusion (VI). Based on studies presented in this paper, however, this compound has become more frequently detected in indoor air and is likely attributed to sources in the buildings being sampled. This paper summarizes current knowledge of indoor air background levels of 1,2-dichloroethane and potential sources. Recent field data demonstrate that the typical indoor air concentrations for this compound are higher than those reported in the past and may be connected to a larger presence of internationally shipped materials in the current indoor environment than in previous decades. This is an important consideration when evaluating buildings for VI, as background indoor air concentrations of 1,2-dichloroethane may confound the VI pathway assessment.

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Senthilselvi, D. A.

Air Quality Monitoring System Using FOG Computing.

International Journal for Research in Applied Science and Engineering Technology, Vol. **13** n°(5), (2025), 1785-1793 p.

The focus of this project is real time Air Quality Monitoring (AQI) within indoor environment using a hybrid Edge– Fog–Cloud architecture. The edge node is an ESP32 microcontroller and PMS5003 particulate matter sensor pair that collects, and preprocesses data for air quality, including PM1.0, PM2.5 and PM10 concentration. Data collected from the edge node is sent to a local Fog node that consists of an InfluxDB instance running in Docker container which gives the advantage of low latency data storage, processing and real-time alerts generation. In order to scale and ensure long term analytics, the fog node writes the data to an InfluxDB Cloud instance to store the data long time and make it remote available. Dashboard with InluxDB's native visualization tools helps to get current and historical air quality trends. The Fog layer monitors continuously and remains resilient in the case of network outages while the Cloud layer is for large scale data analysis and report generation. The system responsiveness is optimized with this hybrid architecture, so as to reduce the reliance on external networks to carry out critical operations and to achieve a scalable solution for indoor air quality management. In future, multi room expansion, more advanced alerting mechanisms and predictions of air quality deterioration are also expected.

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Montaño, R. R., Alarcón-Sánchez, M. A., Nieto, M. M., Hernández, J. J. V., Martínez, S. M. L.

Application of nanotechnology to dentistry: Impact of graphene nanocomposites on clinical air quality.

World Journal of Clinical Cases, Vol. **13** n°(8), (2025)

Concerns about air quality in dental clinics where aerosol generation during procedures poses significant health risks, have prompted investigations on advanced disinfection technologies. This editorial describes the strengths and limitations of ventilation and aerosol control measures in dental offices, especially with respect to the use of graphene nanocomposites. The potential of graphene nanocomposites as an

innovative solution to aerosol-associated health risks is examined in this review due to the unique properties of graphene (e.g., high conductivity, mechanical strength, and antimicrobial activity). These properties have produced promising results in various fields, but the application of graphene in dentistry remains unexplored. The recent study by Ju et al which was published in World Journal of Clinical Cases evaluated the effectiveness of graphene-based air disinfection systems in dental clinics. The study demonstrated that graphene-based disinfection techniques produced significant reductions in suspended particulate matter and bacterial colony counts, when compared with traditional methods. Despite these positive results, challenges such as material saturation, frequency of filter replacement, and associated costs must be addressed before widespread adoption of graphene-based disinfection techniques in clinical practice. Therefore, there is need for further research on material structure optimization, long-term safety evaluations, and broader clinical applications, in order to maximize their positive impact on public health.

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Wang, S.

Automated fault diagnosis detection of air handling units using real operational labelled data and transformer-based methods at 24-hour operation hospital.

Building and Environment, Vol. **282**, (2025)

Automated Fault Detection and Diagnosis (AFDD) in Air Handling Units (AHUs) is essential for maintaining indoor air quality and extending the lifespan of HVAC systems. However, previous research has frequently been constrained by limited access to real operational data, primarily due to difficulties in data collection and complexities associated with accurate fault annotation. Additionally, transformer-based methods remain underutilized in AFDD applications despite their proven effectiveness in related domains. In this study, AHUs equipped with Constant Air Volume (CAV) systems operating continuously in a 24-hour hospital environment were specifically investigated. Data were collected over a one-year period using nine different sensors installed across eight AHUs. Four operational conditions were identified: normal operation and three distinct types of faults. Three transformer-based models—TFT, Informer, and Autoformer—were proposed and optimized through comprehensive hyperparameter tuning, resulting in the evaluation of a total of 792 models. Additionally, 1076 models based on seven traditional machine learning methods were optimized and evaluated. A detailed comparative analysis revealed that the Autoformer model outperformed all other evaluated methods, achieving an F1 score of 96.21 % and an accuracy of 96.02 %. Moreover, the Autoformer demonstrated efficient performance, capable of processing approximately 37.88 instances per second. The potential practical applications and implications of these findings for real-world operational conditions are further discussed in this research.

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Aldoori, Z., Sheta, W.

Beyond Taste: Investigating Indoor Air Quality in Sharjah's Restaurants.

BUiD Doctoral Research Conference 2024

Indoor Air Quality (IAQ) is crucial for customer satisfaction and well-being in restaurants but is often overlooked. As Sharjah becomes a global gastronomic hub, it is essential to address the complex issues of IAQ, which are linked to health, environmental, and climatic issues. International organizations like ASHRAE and WHO have enacted strict regulations and policies in order for improvement and maintenance of IAQ within the criteria of health and comfort. This study examines toxic air pollutants in a café setting to determine if they meet global requirements and standards. The majority of customers were satisfied with the staff's service and saw no difference in their work rate, indicating a high standard of indoor air quality which satisfies the United Arab Emirates' Indoor Air Quality standard.

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Wang, H., Deng, M., Wang, M., Chi, Y., Tham, K. W., Li, C.

BTEX pollution and health effects in a metro system.

Building Simulation, Vol. **18** n°(5), (2025), 1143-1162 p.

As an integral component of modern urban transportation, metro systems have significantly contributed to alleviating urban traffic congestion and reducing carbon emissions. However, concerns about air quality in its confined environment, particularly the pollution by BTEX (benzene, toluene, ethylbenzene, and xylene), are growing. This study takes the Chengdu metro system as a case to evaluate the concentrations of BTEX and their potential health impacts on the public. Sampling was conducted in metro stations, carriages, and tunnels. The study found that the BTEX pollution levels in the metro system were 7.85 ± 3.03 μg/m3 in summer and 8.44 ± 3.38 μg/m3 in autumn, with toluene and xylene being the highest concentrations. No significant differences were observed between the halls and platforms, interchanges and non-interchanges, off peak and evening peaks in carriages, or in-service and off-service in tunnels. However, seasonal variations were pronounced. Health risk assessments indicated that while non-cancer risks were negligible, cancer risks in both summer and autumn (excluding passengers) exceeded the acceptable threshold of 1 × 10−6, potentially posing health threats to long-term exposed populations, particularly metro workers. This study provides a scientific basis for air quality management within metro systems and highlights the need for regulatory bodies to pay further attention to air quality issues, promoting the formulation and implementation of relevant control measures to protect the health and safety of passengers and metro workers.

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Jia, Z., Zhang, Z., Tan, H., Chen, J., Zhu, L., Wang, L.*, et al.*

Characterizing volatile organic compounds from personal protective equipment users: Implications to cleanroom air quality and occupational health.

Journal of Hazardous Materials, Vol. **495**, (2025)

Human-related contaminants are the primary pollution source in cleanrooms. This study employed time-of-flight mass spectrometry (PTR-ToF-MS) to characterize volatile organic compound (VOC) emissions from breath and skin under different activity levels and personal protective equipment (PPE) conditions in a climatic chamber. The results show that, without PPE, breath and skin emission rates were 968.2 ± 350.8 μg h−1p−1 and 2115.8 ± 1813.7 μg h−1p−1, respectively. With PPE, breath emissions slightly increased to 1068.6 ± 472.7 μg h−1p−1, while skin emissions stabilized at 2181.1 ± 1302.5 μg h−1p−1. Key VOCs included acetone, isoprene, and ethanol from breath, and propanamide, acetone, and isoprene from skin. Activity levels increased skin emissions, but prolonged PPE use reduced them. Females showed higher sensitivity to PPE in breath emissions, while males were more sensitive in skin emissions. PPE had minimal efficacy in mitigating the outward emission of skin VOCs into the ambient environment. The hydroxyl radical reactivity and secondary organic aerosol formation potential from human-related VOCs were 0.27 ± 0.08 s−1 and 2.13 ± 0.51 μg m−3, respectively. Breath VOCs, especially acrolein and acetaldehyde, pose significant health risks to users and may affect industrial processes. These findings highlight the importance of human activities in VOC emissions, crucial for contaminant control, health assessments, and industrial processes like semiconductor cleanrooms.

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Pane, D. D., Ardito, A., Sitompul, E., Khairani, N., Nababan, M. N. K.

Comparative Study of Forecasting Models for Smart Campus Air.

Sinkron : jurnal dan penelitian teknik informatika, Vol. **9** n°(2), (2025), 925-935 p.

Air quality monitoring has become increasingly critical in urban environments, especially in densely populated smart campuses situated in tropical regions. This study presents a comparative evaluation of three predictive models CNN-GRU, LSTM, and Random Forest, for forecasting air pollution levels, specifically particulate matter concentration (PM), using real-time sensor data. The data were collected from an IoT-based monitoring system built with NodeMCU ESP8266 devices deployed on campus. Each model was trained and evaluated using performance metrics including the coefficient of determination (R^2), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE). The results indicate that the Random

Forest model achieved the highest predictive accuracy with R^2 = 0.9073, MAE = 123.31, and RMSE = 274.45, outperforming both LSTM (R^2 = 0.8341) and CNN-GRU (R^2 = 0.8714). The hybrid CNN-GRU model, although capable of capturing both spatial and temporal dependencies, required larger data volumes and longer training times. The LSTM model, while effective in modeling time-series data, demonstrated a tendency to overfit when data was limited. This study highlights the practical advantages of Random Forest in modeling complex environmental data under limited resource constraints, while also demonstrating the potential of hybrid deep learning architectures. These findings contribute to the development of efficient air quality prediction systems that support health-conscious decision-making and environmental management strategies in tropical innovative campus environments.

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Vives Roura, G.

Creation of a network of distributed gas sensors.

Universitat Politècnica de Catalunya Thèse 2025

This document covers the development of a distributed network of gas sensors useful to monitor the concentration of different gases in any office, car workshops, food conservation environments and other similar spaces. The project aims to design three different modules. The module for offices senses CO2 and volatile compounds (TVOC) concentrations. The module for car workshops senses CO, NOx, and particulate matter (PM) concentrations. The module for food conservation environments senses CO2 and O2 concentrations. In addition, all these modules sense temperature and relative humidity. The development of the project requires to program sensors, to define a communication architecture to send and store sensors' data in a database, to create a graphical user interface (GUI) to visualize data, and to design cases that integrate each module. The hardware needed for the project consists of digital and analogic sensors, and ESP32-based microcontrollers, which can be programmed via Arduino IDE. Regarding communication, the tool Mosquitto allows to use MQTT protocol to transmit data. This data is stored in a database by means of Node-RED and InfluxDB, where data visualization is done. 3D printing is used to create the cases that integrate the modules. The realization of the project gives as a result three fully functional modules that provide CO2, TVOC, CO, NOx, PM and O2 concentration data. All this data can be visualized in a graphical user interface. Lastly, the hardware has been properly integrated in small boxes that provide protection against external agents. It has been surprising to discover how important it is to select the right hardware to meet the requirements set for the system. Powerful and useful tools such as ESP32- based microcontrollers, Mosquitto, Node-RED and InfluxDB have introduced me to the interesting and growing world of Internet of Things

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B, A., Rahamtula, S., S, S., Velayudham, S., C, K., Jagadeesh, C.

Decentralized Air Quality Management using Edge AI and Real-Time Control.

2025 Third International Conference on Augmented Intelligence and Sustainable Systems (ICAISS)

This research introduces a groundbreaking approach to real-time air quality monitoring and control by implementing Edge AI on an Arduino microcontroller. The system is designed to integrate an array of sensors that capture real-time air quality data, which is subsequently processed by optimized machine learning models deployed directly on the edge device. This innovative approach removes the need for cloud connectivity, significantly reducing latency, and enabling a swift response to fluctuating air quality conditions. The use of lightweight neural networks, such as Mobile Net or Efficient Net, ensures the system is highly efficient and suitable for resource-constrained devices. Real-time control algorithms, driven by AI assessments, dynamically adjust air purifiers, ventilation systems, and other mitigation measures to maintain optimal indoor air quality. This Edge AI-powered solution offers a cost-effective and energy-efficient method for enhancing air quality in real-time, with potential applications ranging from smart homes to larger public spaces. By leveraging these advanced technologies, the system not only improves

accuracy and efficiency but also empowers users to take proactive measures for their health and well-being, thereby contributing to a healthier and more sustainable environment.

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Um, C. Y., Delp, W. W., Blacklock, R. C., Singer, B. C.

Demonstration of a novel tracer gas method to investigate indoor air mixing and movement.

Indoor Environments, Vol. **2** n°(1), (2025)

This paper reports on equipment and procedures that enable the application of the pulsed tracer method to study air movement, contaminant transport, and mixing in rooms. We use ethanol as a non-toxic tracer and a network of low-cost, fast response (2 s) metal oxide sensors to measure airborne concentrations at high frequency. The method was demonstrated in a 158 m3 room of the FLEXLAB facility at Lawrence Berkeley National Laboratory, with an overhead HVAC system with controllable supply airflow and temperature. The room was configured as a meeting space with 8 simulated occupants. The sensors were mounted in a 3 × 4 grid in the upper room (0.3 m from the 2.74 m ceiling), in the middle height of the room at 1.1–1.4 m, and at several locations 0.1–0.4 m from the floor. Vaporized ethanol was released in pulses of 20 s. Sensors were cross-calibrated in-situ to provide quantitative information about relative concentrations and exposures. Results show that the method provides quantitative information about air movement patterns and mixing. For example, mixing throughout the room took 3–4 min with high supply airflow at neutral temperature and 7.5–9 min with heated supply air provided at a lower rate. The test can be used to evaluate whether air movement from the occupied zone to the upper room is fast enough to achieve the extremely high air cleaning rates that are possible with upper room germicidal ultraviolet disinfection (GUV) systems under ideal mixing conditions.

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Shinde, P., Ranalkar, M., Anjan, A., Patil, R., Autee, R., Mohapatra, M.

Design, simulation, and fabrication of power optimized MEMS multilayer semiconductor sensor for SO2 sensing.

Discover Sensors, Vol. **1** n°(1), (2025), 10 p.

Amidst mounting global concerns regarding air pollution and its association with climate change, this study introduces a novel concept of multilayer semiconductor sensor chip. Fabricated on a silicon (Si) substrate, the chip incorporates sophisticated microheater elements made up of Platinum (Pt) separated by consecutive insulating layers and interdigitated electrodes coated with gold (Au) material for the gas-sensitive material as tin di oxide (SnO2). The design precision, validated through COMSOL Multiphysics simulations, ensured a secure operational temperature. Rigorous testing with gases such as SO2, NH3, CO, NO2 and H2S shows a remarkable achievement in improved cross sensitivity at low temperature, highlighting the innovation’s robustness. An important aspect of this research is the reduced operational temperature and low power consumption of the SO2 sensor. This technique of multilayer architecture, precise COMSOL simulation, and sputtering methodologies defines the uniqueness of this study. These developments not only enhanced the gas sensor efficiency but also present a promising solution to address the urgent challenges posed by air pollution, marking a significant step forwardness in environmental sensor technology.

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Khankari, K.

Designing Building Ventilation to Exceed Codes and Standards.

ASHRAE Journal, Vol. **67** n°(6), (2025)

The article focuses on the importance of designing building ventilation systems that exceed existing codes and standards to enhance indoor air quality (IAQ). It highlights that while current standards, such as

ASHRAE Standards 62 and 241, provide minimum ventilation rates, they often fail to address the complexities of airflow patterns and the movement of airborne contaminants. The use of computational fluid dynamics (CFD) is proposed as a method to analyze and optimize ventilation designs, allowing for a more human-centric approach that considers the unique airflow dynamics within indoor spaces. The article emphasizes that effective ventilation design should not only ensure adequate air supply but also manage the distribution and removal of contaminants to maintain a healthy indoor environment.

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Wouters, P., Janssens, A.

Developing regulations to improve IAQ, ventilation and airtightness in Belgian buildings.

14th International BUILDAIR Symposium, 16-17 May 2025, Hannover, Germany

The presentation gives an overview of the developments of regulations in the Belgian context with respect to indoor air quality, ventilation and airtightness.

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Gani, S. M. O., Mopidevi, S., Akul, J. R., Naru, T. A., Alayamani, D. A., Thomas, M. N.

Development of a low-cost portable ventilator system with push mechanism for off-grid and remote patient care.

Second International Conference On Robotics, Automation And Intelligent Systems (Icrains 24)

Human lungs draw in air for breathing by using the reverse pressure created by the diaphragm's contraction motion. A ventilator works by pumping air into the lungs, which is a paradoxical motion. The delivery range for a ventilator mechanism should be between 10 and 30 breaths per minute, and it should be able to change the ascending increments in sets of two. Furthermore, the ventilator must regulate the volume of air that enters the lungs with each breath. The last parameter is to alter the length of the inhale to exhale ratio. Additionally, to avoid both over- and under-air pressure, the ventilator has to be able to track the patient's blood oxygen saturation and exhaled lung pressure. The proposed ventilator meets all of these criteria, and it was designed using Atmega8 technology, making it a dependable yet reasonably priced ventilator that can be useful during pandemics. The proposed work integrates the mechanism with the ventilator bag by adopting a two-side push mechanism and a silicon ventilator bag that is attached to DC motors. Toggle switches are used for switching, and a variable pot is used to modify the patient's BPM and breathing duration. This portable device uses a blood oxygen sensor and a pressure sensor to monitor the patient's vital signs and present them on a small LCD display. The portable ventilator is equipped with an emergency buzzer alarm that will ring as soon as an abnormality is found. The developed product is checked in real-time scenarios for different patients with the age limits of 21 - 30 and 31- 40 and produces reliable results. The significance of the work lies in the use of Atmega8 technology to construct a low - cost portable ventilator for remote patient care.

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Nadzir, M. S. M., Rabuan, U., Ali, S. H. M., Borah, J., Majumdar, S., Rohmad, M. S.

Drone-based Air Quality Monitoring: Development and Evaluation of Low-Cost PM2. 5 Sensor for Remote Environmental Assessment.

Sensors and Materials, Vol. **37** n°(6), (2025), 2153-2171 p.

Localized air pollution from open burning, waste disposal, and gas emissions remains difficult to monitor effectively, especially in inaccessible areas. Conventional air quality monitoring methods are often costly, stationary, and inadequate in coverage. We present AirborneSense, a novel unmanned aerial vehicle (UAV)-based monitoring system equipped with low-cost particulate matter (PM2.5) sensors, GPS, and environmental sensors (temperature, humidity, and barometric pressure), using the Global System for Mobile Communications (GSM) to transmit real-time data to the cloud. The HPMA1115 PM2.5 sensor was

chosen for its high accuracy, R2 > 0.7, and a calibrated RMSE of 1.98, compliant with US EPA standards. Field tests were carried out at various altitudes and locations to evaluate system accuracy and adaptability. At higher altitudes, AirborneSense demonstrated its peak sensor performance with an R2 value of 0.78, maintaining consistency with reference analyzers (R2 = 0.73). The system effectively mapped pollution, revealing elevated PM concentrations in construction zones and significantly lower levels in rural areas. The findings underscore the potential of UAV-based systems to enhance spatial and temporal environmental assessments, pro

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Kim, J., Son, J., Koo, J.

Dynamic Estimation of PM2.5 Penetration and Removal Rates Using Physics-Informed Neural Networks for Indoor Air Quality Management.

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

Quantifying indoor air pollutant dynamics is crucial for assessing exposure risks and optimizing ventilation strategies. This study advances previous research by developing a Physics-Informed Neural Network (PINN) model that dynamically estimates ventilation rate, penetration factor, and particulate removal rate in real time. The model integrates space operation factors (e.g., occupancy, window/door status, air purifier and air conditioner use) and meteorological variables (e.g., temperature, humidity, wind conditions, and outdoor $PM_{2.5}$ levels) to predict indoor $PM_{2.5}$ behavior without assuming static coefficients. A key contribution of this study is the application of SHapley Additive exPlanations (SHAP) to quantitatively analyze the influence of each variable. The results indicate that outdoor humidity, window opening, and occupancy significantly impact the penetration factor, while air purifier operation, occupancy, and window opening play major roles in particulate removal. Notably, this study identifies a previously unreported effect: occupancy enhances removal rates due to particle inhalation, allowing for a direct estimation of personal exposure. Specifically, the mass flow rate of $PM_{2.5}$ inhaled per occupant is approximately 10 times the indoor $PM_{2.5}$ concentration (μg/hour). This approach refines traditional exposure assessments by quantifying $PM_{2.5}$ uptake per person. While the model is currently specific to a single measured space, it provides a practical tool for real-time air quality management. Future research will focus on expanding its applicability through long-term data collection across diverse environments and integrating reinforcement learning to optimize air quality control strategies. This study lays the groundwork for adaptive ventilation management, balancing air quality improvements with energy efficiency.

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Al-Sayyab, A. K. S., Navarro-Esbrí, J., Barragán-Cervera, A., Mota-Babiloni, A.

Effect of compressor speed on heat pump performance with climate-friendly refrigerants.

International Journal of Refrigeration, Vol. **177**, (2025), 296-304 p.

The sustainability of the Heating, Ventilation, and Air Conditioning (HVAC) system focuses on reducing energy consumption, improving efficiency, minimising environmental impact, and improving indoor air quality while maintaining comfort. Sustainable HVAC practices are critical in combating climate change and creating energy-efficient systems. A Variable Refrigerant Flow (VRF) is an HVAC technology that utilizes high-efficiency components of variable-speed compressors enabled by inverter technology. These compressors adjust cooling output to actual demand and contribute to the system's overall energy efficiency, unlike conventional systems that operate at full capacity and use more energy. Thus, VRFs are highly efficient, adaptable, and suitable for various building types. The current study compares climate-friendly refrigerants R1234yf and R515B under different compressor frequencies (35, 40, 45, and 50 Hz). The experiment was carried out under the secondary fluid inlet and outlet temperatures of (12 °C/6 °C in the case of glycol and 45 °C/50 °C in the case of water), respectively. While the degree of sub-cooling and superheat is maintained at 5 °C and 10 °C, respectively. R1234yf demonstrated the highest refrigerant mass flow rate under the tested frequency, increasing compressor power consumption. R515B presents

the highest system COP over all tested compressor frequencies, which can be selected as a suitable, safe, and non-flammable alternative refrigerant in buildings.

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Tsai, C., Cheng, H., Hsu, L.

The Effectiveness of Energy Recovery Ventilation (ERV) to Improve the Indoor Air Quality.

Int J Eng Tech & Inf, Vol. **6** n°(1), (2025), 1-8 p.

This study aims to achieve air cleaning by utilizing the energy recovery ventilation (ERV) to introduce outdoor fresh air into the conditioned space to reduce indoor CO2 and particulate matter concentrations and recover energy simultaneously. The CO2 and particulate matter concentrations were measured to observe the difference after turning on the ERV. It was found that the ERV led to reduce the CO2 concentration significantly. With the ERV activated, the concentration of CO2 reached below the standard level less than 100 minutes, reaching a minimum of 420ppm; while the concentration of PM2.5 remains between 6- 10µg/m3. An additional air duct facilitating ERV drawing air from stagnant area was helpful. By installing additional air duct, the problem of some poor circulation area was solved, and the concentration of CO2 was confirmed to decrease to a minimum of 525ppm. The ERV was proved as a good and easy way to enhance indoor air cleaning.

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Manjula, B., Chaitanya, T., Karedla, P., Pravallika, V., Srujana, K.

Enhancing Indoor Environment with Smart Ventilation.

2025 5th International Conference on Pervasive Computing and Social Networking (ICPCSN)

This project aims to improve indoor air quality (IAQ) through a smart ventilation system powered by IoT technology. The proposed solution demonstrates the potential of IoT-driven systems in addressing indoor air quality challenges, offering a scalable and cost-effective approach for maintaining healthy indoor environments. The system uses real-time monitoring and automated control to maintain a healthy indoor environment. The ESP8266 module ensures seamless connectivity and data transmission between sensors and the control system. The system detects harmful gases, temperature, and humidity levels and adjusts ventilation dynamically to ensure optimal air quality. This automated approach minimizes energy consumption while maintaining a comfortable and healthy environment. The system is portable and adaptable, suitable for various indoor settings, including homes, offices, and industrial spaces.

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Park, S., Lee, H., Song, D.

Estimation of infiltration rate using occupant-generated CO_2: Filtering process for uncertainty reduction.

Building and Environment, Vol. **282**, (2025)

The occupant-generated CO_2 concentration decay method has garnered significant attention because it eliminates the need for repeated gas injections and enables air infiltration rate calculation using only indoor and outdoor CO_2 monitoring. This approach facilitates easy calculation of the infiltration rate based on the decay history of the indoor CO_2 concentration, which increases owing to occupants' respiration and decreases after their departure, using the mass balance equation. However, depending on the expertise of the researcher, the selection of an inappropriate decay period can lead to either overestimation or underestimation of the infiltration rate. This paper discusses three key considerations for ensuring reliable infiltration rate estimation using occupant-generated CO_2 and presents a filtering process. The increased measurement uncertainty in the later phase of CO_2 decay, when small changes in concentration affect the accuracy of infiltration rate estimates is discussed, and a filtering method to improve reliability is introduced. The overestimation caused by non-uniform CO_2 concentrations during the initial phase of decay is then

addressed, suggesting a filter to correct this. Finally, the optimal point for minimizing measurement uncertainty in the final calculation is identified. The proposed process is evaluated using long-term field measurements and validated by comparing the calculated infiltration rates with those obtained using traditional tracer gas decay methods. This process allows daily variations in infiltration rates to be reliably estimated using only CO_2 monitoring, offering a valuable tool for improving indoor air quality and reducing energy consumption through integration with HVAC systems and energy simulations.

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Pradhan, D. S., Patra, A. K., Penchala, A., Santra, S.

Estimation of real-time PM exposure and associated health risk of HEMM operators using low-cost sensors in a highly mechanised opencast coal mine.

Air Quality, Atmosphere & Health, (2025)

The working environment of the operators of heavy earth moving machineries (HEMMs) expose them to high airborne particulate matter (PM) concentration as a part of their occupation. Using a set of low-cost sensors, the present study investigated the in-cabin PM exposure of dumper, shovel and drill machine operators and compared it with the cabin outside PM concentration in a large opencast mine where a large number of HEMMs are deployed. The results revealed that the drill operators were exposed to the highest in-cabin PM concentration (PM1 = 190.98 ± 30.3 μg m−3, PM2.5 = 281 ± 52.85 μg m−3, PM10 = 1475.23 ± 915.42 μg m−3) followed by the exposures of shovel (PM1 = 45.62 ± 24.28 μg m−3, PM2.5 = 97.85 ± 51.10 μg m−3, PM10 = 354.38 ± 219.69 μg m−3) and dumper operators (PM1 = 42.08 ± 18.25 μg m−3, PM2.5 = 90.38 ± 44.55 μg m−3, PM10 = 331.05 ± 225.65 μg m−3). The exposure in the evening shift was 10% higher than exposure during the morning shift. The in-cabin PM concentrations while the dumper travelled on main haul road were ~ 2 times of the corresponding values when it travelled on the internal haul road. In addition to the outside concentration, the in-cabin PM levels are influenced by cabin ventilation (AC vs. non-AC), structural leakage, and door/window operation. AC cabins could reduce the PM exposure up to 40% (10% for non-AC cabins) than ambient mine environments. GLM explained 65–89% of PM concentration variability, with HEMM type and meteorological parameters as significant predictors. The health risk assessment indicates that all operators are exposed to non-carcinogenic health risks, as the Risk Quotient (RQ) values for each exceed the threshold of 1 (RQ > 1). Notably, the drill operator is subjected to the highest non-carcinogenic risk, with an RQ value of 8. While, the Excess Lifetime Cancer Risk (ELCR) assessment for PM2.5 exposure reveals potential carcinogenic risks among operators in two age groups. For the 18-year age group, the ELCR values range from 6.15×10^{-4} to 1.92×10^{-3}, whereas for the 21 years and above age group, the values range from 5.13×10^{-4} to 1.60×10^{-3}, indicating elevated cancer risk among 18 + age group of operators. This research highlights the occupational health risk of the HEMM operators working in opencast mines and important role of low-cost sensors in real-time PM exposure assessment in mining environments.

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Stenech, M., Decitre, G., Brenn, G., Irrenfried, C.

Experimental investigation of the ventilation efficiency for single-sided ventilation in suburban areas.

Building and Environment, (2025)

Natural ventilation is a key passive design strategy for enhancing indoor air quality and reducing energy consumption in buildings. This study investigates natural ventilation and associated transport mechanisms using a small-scale model building in a boundary layer wind tunnel, replicating suburban terrain conditions. Ventilation performance was quantified via tracer gas concentration decay, revealing optimal ventilation efficiency at a wind incidence angle of 85°. Flow structures were examined through Particle Image Velocimetry and tuft probe measurements to investigate the underlying transport processes. The results demonstrate that broadband ventilation dominates across a wide range of incidence angles, while eddy penetration becomes increasingly influential between 75° and 90°. A strong positive correlation was

identified between internal velocity magnitudes and ventilation rates, with high internal velocities and external flow separation bubbles near the window significantly enhancing ventilation efficiency. These findings highlight the importance of external flow topology in controlling internal air exchange and show the significance of oblique wind directions in promoting effective ventilation. The results provide valuable guidance for façade design and window placement in naturally ventilated buildings, particularly in suburban settings with complex wind environments. The insights contribute to improved predictive capabilities for ventilation modeling and offer evidence-based recommendations for optimising passive ventilation strategies in early-stage building design.

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Borrelli, R., Cecconi, A., Oldani, A., Fuin, F., Emiliani, R., Cacciari, F.*, et al.*

Field Comparison of Active and Passive Soil Gas Sampling Techniques for VOC Monitoring at Contaminated Sites.

In: Environments. 2025.

This study presented a comprehensive comparison of soil gas sampling methodologies to monitor volatile organic compounds (VOCs) at two industrial sites in northern Italy. Utilizing active sampling techniques, such as stainless-steel canisters, vacuum bottles, and sorbent tubes, alongside passive methods like low-density polyethylene (PE) membranes, sorbent pens, and Waterloo Membrane Samplers (WMS), the research examines their effectiveness under varied environmental conditions. Five field campaigns were conducted in two areas of the industrial sites characterized by BTEX and chlorinated solvent contamination. The results highlighted that active sampling, while expensive, provides real-time, high-resolution VOC concentration data, often outperforming passive methods for heavier compounds (e.g., hexachlorobutadiene). However, using the active systems in certain campaigns, challenges such as high soil humidity or atmospheric air infiltration were observed, resulting in an underestimation of the soil gas concentrations. Passive sampling systems demonstrated cost-effective, efficient alternatives, offering consistent spatial and temporal coverage. These methods showed alignment with active techniques for lighter compounds (e.g., TCE and BTEX) but faced limitations in sorbent saturation and equilibrium time for heavier VOCs (e.g., hexachlorobutadiene), requiring adjustments in exposure duration to enhance accuracy. PE samplers provided results comparable to active methods, especially for BTEX and TCE, while WMS and sorbent pens exhibited lower sensitivity for certain analytes. This underscores the importance of optimizing sampler configurations and deployment strategies. The findings emphasize the value of integrating active and passive approaches to achieve robust VOC assessments in heterogeneous subsurface environments.

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

Field Investigation of Thermal Comfort and Indoor Air Quality Analysis Using a Multi-Zone Approach in a Tropical Hypermarket.

Buildings, Vol. **15** n°(10), (2025)

Indoor environmental quality (IEQ), encompassing thermal comfort and indoor air quality (IAQ), plays a crucial role in occupant well-being and operational performance. Although widely studied individually, integrating thermal comfort and IAQ assessments remains limited, particularly in large-scale tropical commercial settings. Hypermarkets, characterised by spatial heterogeneity and fluctuating occupancy, present challenges that conventional HVAC systems often fail to manage effectively. This study investigates thermal comfort and IAQ variability in a hypermarket located in Gombak, Malaysia, under tropical rainforest conditions based on the Köppen–Geiger climate classification, a widely used system for classifying the world's climates. Environmental parameters were monitored using a network of IoT-enabled sensors across five functional zones during actual operations. Thermal indices (PMV, PPD) and IAQ metrics (CO2, TVOC, PM2.5, PM10) were analysed and benchmarked against ASHRAE 55 standards to assess spatial variations and occupant exposure. Results revealed substantial heterogeneity, with the

cafeteria zone recording critical discomfort (PPD 93%, CO2 900 ppm, TVOC 1500 ppb) due to localised heat and insufficient ventilation. Meanwhile, the intermediate retail zone maintained near-optimal conditions (PPD 12%). Although findings are specific to this hypermarket, the integrated zone-based monitoring provides empirical insights that support the enhancement of IEQ assessment approaches in tropical commercial spaces. By characterising zone-specific thermal comfort and IAQ profiles, this study contributes valuable knowledge toward developing adaptive, occupant-centred HVAC strategies for complex retail environments in hot-humid climates.

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Çinar, E., Abut, T.

Fuzzy LQR-based control to ensure comfort in HVAC system with two different zones.

Case Studies in Thermal Engineering, Vol. **73**, (2025)

Heating, ventilation, and air conditioning (HVAC) systems are control systems that ensure indoor temperature and air quality meet desired conditions. In this study, a novel control strategy is proposed for an HVAC system operating under two distinct environmental zones with variable flow rates, addressing control challenges arising from external disturbances such as ambient temperature and humidity changes. In the system design, mathematical models were obtained, including the heat losses of two zones to the outdoor environment, as well as the heat transfer dynamics in the cooling unit, fans, and air ducts. For system control, considering ambient temperature, humidity, and variable flow rate, the required airflow was achieved by controlling the dampers placed in the indoor air inlet ducts. The core novelty of this work lies in the development and comparison of advanced control algorithms, including the Linear Quadratic Regulator (LQR), a Particle Swarm Optimization (PSO)-based LQR, and a newly designed PSO-based Fuzzy LQR (FLQR) controller. Comfort conditions were achieved by cooling the temperatures of two different regions from the ambient temperature to approximately 7 °C. The proposed FLQR controller combines the adaptability of fuzzy logic with the optimization capabilities of PSO to enhance system responsiveness and occupant comfort. Simulation results show that the FLQR method improves comfort performance by 90.4 % for Zone-1 and 88.1 % for Zone-2 compared to conventional LQR. The effectiveness of the proposed method (FLQR) is demonstrated through a comprehensive performance evaluation using Mean Squared Error (MSE) metrics, confirming its potential for intelligent HVAC applications.

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Lee, Y., Lee, S., Jang, W., Lee, J., Choi, Y., Lim, S.-H.

Hybrid GC platform: a micro gas chromatography system with a simple configuration for low-concentration VOC analysis.

Lab on a Chip, (2025)

A compact hybrid gas chromatography (GC) platform was developed by integrating a previously reported hybrid μ-GC column chip (hybrid chip) and a commercial photoionization detector. The hybrid chip enabled both gas preconcentration and separation in a single device, allowing for a highly compact and simple platform design with a volume of 0.62 L. With a sample volume of 40.8 mL and an analysis time of 20 minutes, it achieved detection limits of 19.3, 22.8, 30.4, and 24.4 ppb for benzene, toluene, ethylbenzene, and ortho-xylene, respectively. The linear ranges were 0.25–1 ppm for benzene and toluene, 0.25–1.5 ppm for ethylbenzene, and 0.25–2 ppm for ortho-xylene. The peak capacity ranged from 5.34 to 8.81, with full width at half height between 0.22 and 0.5 min. Importantly, the detection limit for benzene was below US workplace air concentration limits set by the American Conference on Governmental Industrial Hygienists (ACGIH) and National Institute for Occupational Safety and Health (NIOSH), demonstrating the platform's potential for indoor air monitoring. Furthermore, portability was enhanced through the integration with a battery and carrier gas filter pack. The platform consumed 2.65 W during analysis (20 minutes), and assuming one cycle consists of 20 minutes of analysis and 10 minutes of stand-by operation, the system could theoretically operate for 70 cycles (35 hours) on a single charge. Field testing with classroom and laboratory air samples confirmed the potential applicability of the platform. In addition, partial qualitative

separations were achieved for alkanes, alcohols, aldehydes, and ketones, suggesting broader utility in fields beyond indoor air monitoring.

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Liu, S., Wang, Y., Xiao, Y., Guo, W., Li, Y., Lu, Y.*, et al.*

Impact of occupancy density and source location on inhalational exposure of infectious respiratory particles in a naturally ventilated fever clinic.

Building and Environment, Vol. **276**, (2025)

Infectious respiratory particles (IRPs) exhaled by infected patients significantly influence the safety of susceptible patients in fever clinic waiting areas. Understanding the impact of occupancy density (OD) on the IRPs transmission is essential. This study employed real-time CO2 monitoring to assess fever clinic ventilation performance. The findings revealed an average air change per hour (ACH) of 2.2, below the recommended 6 ACH for infection control. The effects of high, medium, and low OD on the IRPs transmission were analyzed using computational fluid dynamics at 2.2 ACH, considering scenarios where the infected patient was located upstream, downstream and in the seating area of the waiting area. The results showed that IRPs released from the upstream infector had the highest suspension rates, ranging from 14 % to 20 %, while IRPs from other locations had suspension rates below 5 %. Further analysis indicated that the maximum and upper quartile intake fraction (IF) in susceptible populations caused by upstream infectors decreased as OD decreased. At high OD, the upper quartile IF was 0.1 %, which was 1.5 and 2.1 times higher than at medium and low OD, respectively. This decreasing trend was not observed for downstream and seating area infectors. Significance test revealed that IF at high OD was significantly higher than at medium OD only at seating area infectors, with no significant difference in other scenarios. In conclusion, fever clinics with insufficient ventilation should prioritize increasing ventilation rates over merely reducing OD to control infection risks.

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Pepe, C., Ali, M. F., Zanoli, S. M.

Impact of Wind Speed Look-Ahead Mismatch on Carbon Dioxide-based IAQ Nonlinear MPC.

2025 26th International Carpathian Control Conference (ICCC)

Heating, Ventilation and Air Conditioning sector needs reliable control systems associated to Indoor Environment Quality. Indoor Air Quality parameters, e.g., carbon dioxide, cover a crucial role in this context. The present paper investigates the impact of wind speed look-ahead (previewing) mismatch on carbon dioxide Model Predictive Control. The considered case study is represented by an office characterized by two windows that allow natural ventilation. Natural ventilation is obtained through the manipulation of the windows opening. A nonlinear model is exploited for simulations and for control purposes. The carbon dioxide level represents the Controlled Variable while Disturbance Variables are occupancy and wind speed. The impact of wind speed look-ahead (previewing) mismatch on carbon dioxide Model Predictive Control is assessed through specific simulations on significant scenarios that take into account wind speed overestimation, underestimation, and exact knowledge.

Heating, Ventilation and Air Conditioning sector needs reliable control systems associated to Indoor Environment Quality. Indoor Air Quality parameters, e.g., carbon dioxide, cover a crucial role in this context. The present paper investigates the impact of wind speed look-ahead (previewing) mismatch on carbon dioxide Model Predictive Control. The considered case study is represented by an office characterized by two windows that allow natural ventilation. Natural ventilation is obtained through the manipulation of the windows opening. A nonlinear model is exploited for simulations and for control purposes. The carbon dioxide level represents the Controlled Variable while Disturbance Variables are occupancy and wind speed. The impact of wind speed look-ahead (previewing) mismatch on carbon dioxide Model Predictive Control is assessed through specific simulations on significant scenarios that take into account wind speed overestimation, underestimation, and exact knowledge.

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Juárez, M. a. C., González, R. A., Barboza, Y. D. R., Rodríguez, J. S., Correa, S. R.

Implementación de un dispositivo iot para la evaluación de la calidad del aire en interiores de autobuses (implementation of an iot device for indoor air quality assessment in buses).

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

Monitoring indoor air quality is relevant, as people spend 90% of their time indoors, where exhaled aerosols can remain suspended for long periods, increasing the risk of respiratory diseases. Public transport in Mexico is a dynamic environment that confines many people in small spaces during peak hours. This study contextualizes an IoT device with a low-cost sensor to monitor particulate matter (PM) 2.5 and PM10 on three bus routes, conducting measurement campaigns and analyzing the data under various ventilation and occupancy conditions. The results show the PM levels to which a regular bus user is exposed during peak hours and corroborate that IoT technologies offer an accessible solution for continuous indoor air quality monitoring and might support the implementation of public health policies.

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Arghand, T., Melikov, A., Bolashikov, Z., Mustakallio, P., Kosonen, R.

Individually controlled localized chilled beam combined with chilled ceiling: Thermal environment.

Building and Environment, Vol. **282**, (2025)

This study evaluates the performance of an individually controlled localized chilled beam combined with a chilled ceiling system (LCBCC) in a test room under summer conditions using physical measurements and thermal manikin experiments. The thermal environment generated by the LCBCC is compared with the mixing ventilation combined with a chilled ceiling system (MVCC) at room temperatures of 26°C and 28°C. Results indicate that compared to MVCC the LCBCC improved the thermal environment at the targeted workstation exposed to strong radiant asymmetry from the window, while maintaining a comparable thermal environment in the remaining part of the occupied zone. Measurements of air velocity, air temperature, and radiant temperature asymmetry confirm that LCBCC mitigates localized heat sources and provides a comfortable thermal environment with minimal risk of discomfort, such as draught. Whole-body and segmental equivalent temperatures derived from manikin data closely correlate with human subject responses from the previous study, demonstrating their reliability in predicting thermal sensation. The study also highlights the importance of individual airflow control in adapting to occupant-specific preferences and activities. Findings of the study offer insights for optimizing LCBCC design, operation, and integration in practical applications.

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Seddiki, M., Vishakha, V., Gokay, D., Bennadji, A.

Indoor air quality impacts of humidity-sensitive passive ventilation in domestic housing retrofit.

ICAT 2025

The retrofit of existing residential buildings is a crucial strategy for reducingenergy costs, cutting carbon emissions, and improving comfort. Among the retrofit solutions,the adoption of ventilation systems is a necessary approach to ensure appropriate indoor airquality. To date, many studies have analysed the impact of mechanical and naturalventilation on indoor air quality in domestic buildings. Conversely, there is a lack of researchthat has looked at the impact of humidity-sensitive passive ventilation on indoor air qualityin existing domestic buildings. The study aimed to investigate the impacts of installing aninnovative humidity-sensitive passive wall vent on indoor air quality in UK domesticbuildings. The study compared the indoor environment before and after the installation of thehumidity-sensitive passive wall vent in terms of temperature, relative humidity, and CO2concentration. A single-point sampling methodology was adopted wherein Testo 160 IAQsensors were installed in the living room and bedroom of the case study. Findings indicatethat the installation of the system results in a decrease in average CO2 levels. However, thesystem

was unable to maintain consistently, CO2 concentrations below 1000 ppm at alltimes. This research highlights the potential of humidity-sensitive passive ventilation systemsto enhance indoor air quality in domestic retrofit project

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Said, M., Puspitasari, D., Sahim, K.

Influence of exhaust fan position and the addition of secondary exhaust fan to control indoor air pollution (iap) inside a parking garage.

Journal of Applied Engineering Science, Vol. **22**, (2024), 634-645 p.

Air pollution has significantly deteriorated air quality in many urban areas, leading to numerous health issues. This pollution is not confined to outdoor environments but also affects indoor spaces, such as parking garages in basements. One major concern is cold-start emissions from idling cars, which produce higher concentrations of pollutants compared to normal hot emissions. Internal Combustion Engine Vehicles (ICEVs) emit cold-start emissions during the first few minutes after ignition. To mitigate this impact, parking operators typically use exhaust fans to replace polluted air with fresh air. However, the design and placement of the exhaust fan should be optimized to ensure a healthy indoor environment and efficient energy use. This research examines the concentration of air pollutants in a parking garage with three idling cars, focusing on the effectiveness of an exhaust fan installed in two different positions: near the parking spaces and near the pathway. Additionally, the research evaluates the impact of the exhaust fan's position and the inclusion of a secondary exhaust fan on carbon monoxide (CO) concentration during cold-start emissions. The results indicate that the primary exhaust fan should be installed in Position A, as it provides better airflow distribution and effectively extracts air pollutants. Improper airflow distribution, observed when the exhaust fan is installed in Position B, results in some measurement points showing high CO concentrations, with the highest average concentration reaching 68.9 ppm. Furthermore, the addition of a secondary exhaust fan helps reduce the average CO concentration and shortens the duration of the cold-start emission effect.

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Azizah, D. N., Heranurweni, S., Idris, L. O. M.

Internet of Things Based Air Quality Monitoring System with Automatic Notification.

MALCOM: Indonesian Journal of Machine Learning and Computer Science, Vol. **5** n°(3), (2025), 776-787 p.

Internet of Things (IoT)-based air quality monitoring systems represent a significant advancement in urban environmental management. This research implements a system that integrates PM2.5, PM10, CO2, and NO2 sensors for real-time monitoring of pollutants. The results showed that the integration of IoT technology with cloud computing and machine learning algorithms successfully created a responsive and accurate monitoring system. The model achieved maximum accuracy during the training process, with promising predictive capabilities in real-world implementation. The main findings of the study confirmed that the Weighted Class (WC) approach significantly improved performance in the testing and prediction process by addressing class imbalance in the dataset, while the Data Augmentation (DA) technique did not show the expected improvement due to the intrinsic characteristics of air quality data. The automatic notification system successfully provides early warnings when air quality exceeds specified thresholds, enabling proactive responses from authorities and the public. The implementation of a web-based monitoring dashboard provides comprehensive visualization of data for long-term analysis. This research contributes to the development of smart cities by providing an effective framework for air quality management, supporting data-driven decision-making, and increasing public awareness of environmental conditions.

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Biju, P., Saumer, B., Sheta, W.

Investigating Indoor Air Quality in UAE Restaurants: A Case Study.

Particulate matter, oxides of carbon and volatile organic compounds released during cooking can have a harmful impact on the health of employees and clienteles of restaurants. Hence it is crucial to monitor and maintain a healthy indoor air quality (IAQ) of restaurants and this study intends to assess the parameters of indoor air quality of a busy restaurant in Dubai with the intention to offer recommendations to enhance the indoor environment of the restaurant. Following a preliminary assessment and quantitative walk-through inspection of the kitchen and dining area, a survey was administered to the restaurant's staff and patrons in order to determine quality of interior environment. The responses received for the employees' survey emphasised the areas of concern as well as the variables that needed to be assessed and monitored in order maintain the indoor air quality at desired levels. Using the compatible instruments, parameters such as PM2.5, PM10, Temperature, Humidity, Interior Lighting, CO2, CO, and Total VOCs were measured to evaluate the indoor air quality. While analysing the results it was observed that cooking activities in the kitchen are producing particulate matter to an undesired level and augmentation of ventilation is required to maintain a healthy working atmosphere for the employees. Customer response was satisfactory on the quality of indoor environment of the restaurant as per Likert 5-point analysis.

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Gorade, N. B., Galhe, D. S.

Iot-based indoor air quality detection and smart energy management for hvac system.

KT Journal of Mechanical Engineering, Vol. **2** n°(1), (2025), 1-10 p.

Indoor air quality has become a growing concern due to increased indoor time and health risks linked to poor air quality. This project presents the development of an IoT-based system for monitoring indoor air quality and enabling smart energy management of HVAC systems. The system integrates various sensors, including CO_2, gas, smoke, temperature, and humidity sensors, and an ESP32 microcontroller and Blynk app interface to collect, analyze, and display real-time environmental data. In addition to monitoring air quality, the system uses an automated fan control mechanism to respond to deteriorating air conditions, enhancing both comfort and safety. A smart energy management module dynamically controls the HVAC system based on occupancy and air quality levels to reduce power consumption and improve system efficiency. The integration of IoT technology enables real-time feedback, remote access, and energy optimization, making it a cost effective, user-friendly, and scalable solution for residential and commercial applications.

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Gržinić, G., Wolska, L., Rybak, B., Olkowska, E., Nyka, M.

Managing the quality of indoor air in office rooms: looking for a solution.

International Journal of Environmental Science and Technology, (2025)

Good quality of the environment in indoor spaces is an important prerequisite for the health, well-being and productivity of office workers. In cases where poor indoor environmental quality threatens the health and well-being of employees, it is important for the employer to undertake the necessary steps to address these issues. However, very often the employer is not well informed on the proper way to implement the required changes, which can result in suboptimal results and waste of resources. In this work we discuss these issues starting from a case study of the actions taken by the occupational safety and health services at a university situated in the city of Gdańsk, Poland, after complaints regarding health problems and poor well-being due to inadequate indoor air quality, lodged by office workers of the university human resources department. Particular focus is given to the legislative and regulatory aspects of indoor air quality in the European Union and Poland, as well as the impact of remediation. Finally, a suggested general course of action is presented aimed at presenting employers with a procedure for positive resolution of the reported issues using effective methods.

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Liu, J., Dou, W., Meng, X., Wu, J., Ma, Z.

Multi-agent deep reinforcement learning-based hierarchical energy management for better indoor air quality and energy-savings in building energy systems.

Energy Conversion and Management, Vol. **342**, (2025)

Model-free intelligent control strategies in building energy systems (BES) have proven effective for operation flexibility enhancement, real-time decision-making, and multi-energy synergy. However, traditional methods often struggle to achieve safety learning under constraint satisfaction and cannot handle hybrid discrete–continuous control space in BES optimization. Therefore, this work proposes a hierarchical optimization framework using an improved multi-agent deep reinforcement learning algorithm for multi-zone coordination control of BES. Firstly, the hierarchical energy management strategy is established, which decouples discrete operational mode decisions at the upper layer from continuous power adjustments at the middle layer and environmental fine-tuning at the lower layer. Secondly, the option-critic multi-agent twin delayed deep deterministic policy (OCMATD3) algorithm is developed to tackle the optimal control problem of BES. The option-critic policies select discrete operation modes over extended-duration options. While multiple agents perform continuous adjustments in different zones to optimize energy costs and indoor air quality, including air temperature, relative humidity, and indoor CO2 concentration. Thirdly, the safety reward engineering (SRE) mechanism is proposed to enhance the training performance of the agents, which could encourage the agent to satisfy the constraints and correct the agent's violation actions. The developed optimization framework was tested based on a case study building. The results showed that the proposed SRE-OCMATD3 algorithm can achieve the fastest convergence and the best training performance. The hierarchical control strategy achieved, on average, a 14.7 % reduction in operational cost, a 12.6 % reduction in energy consumption, and a 5.6 % decrease in discomfort duration ratio, compared to the single and multi-agent twin delayed deep deterministic policy gradient controllers, multi-agent deep deterministic policy gradient controller, and rule-based control method.

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Nagmani, A. K., Behera, B.

Nanoarchitectonics of high-temperature langasite SAW CO2 gas sensor using ZnO thin film.

Applied Physics A, Vol. **131** n°(6), (2025)

In this paper, a multilayer surface acoustic wave (SAW) device is developed to sense carbon dioxide (CO2) gas concentrations at elevated temperatures. The proposed SAW sensor consists of a ZnO thin film on a Y-cut x-propagated Langasite (LGS) with Euler angle (0°, 138°.5, 26.6°) substrate. A spacer layer of SiO2 film is used between ZnO and LGS substrate for temperature compensation. The ZnO sensing film is inspected towards the maximum coupling factor (K2), the most considerable SAW velocity change, by varying the thicknesses of the film. A 150 nm thickness of ZnO film is optimised with a maximum K2 of 0.52%. The conductivity of the ZnO film is investigated towards the most considerable SAW velocity change, and a conductivity base sensing range is optimised. The operating temperature of 600 °C is optimised for maximum sensitivity towards the effect of operating temperatures. The sensitivity of the multilayer ZnO/SiO2/LGS device is linear, with the CO2 concentrations in the range of 5000 ppm to 25000 ppm. A maximum sensitivity of 2.65 × 10–6 is obtained for 25000 CO2 concentration.

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Almazmumi, S., Sun, H., Liu, M., Calautit, J., Jimenez-Bescos, C.

A novel wall windcatcher (WWC) natural ventilation system evaluated through CFD and experimental field testing - a solution to single-sided ventilation in multi-storey buildings?

Building and Environment, (2025)

As cities grow and building densities increase, maintaining indoor air quality and thermal comfort in multi-story buildings presents a significant challenge. Mechanical ventilation systems, though effective, are energy-intensive, costly to maintain, and contribute to emissions. In contrast, natural ventilation offers a more sustainable alternative but can be constrained by building design limitations, particularly in high-rise or multi-story structures where single-sided ventilation (SSV) may not be able to provide adequate airflow across multiple floors or zones, while adopting other strategies such as cross and wind tower ventilation could be challenging due to the layout of indoor spaces. This study proposes an innovative wall windcatcher (WWC) system to enhance passive ventilation in multi-story buildings. The WWC features an external rectangular ventilation duct mounted on the building façade, incorporating separate channels for supplying fresh air and exhausting stale air, utilizing wind-induced pressure differences. A combined experimental and numerical approach evaluated the WWC's performance through computational fluid dynamics (CFD) simulations and field experiment testing of a scaled model. The CFD model demonstrated good agreement with field measurements, confirming its reliability. Compared to SSV, the WWC improved airflow across all floors and wind angles. At 0° wind direction, airflow increased by 1.2 times on the ground floor, 2.2 times on the first floor, and 1.6 times on the second floor. Even at 90° and 180°, where SSV struggled, the WWC maintained improved ventilation. However, the study also identified airflow reversal in the ground-floor exhaust outlet, leading to inefficient ventilation. To resolve this, the dimensions of the exhaust duct branches were optimized by adjusting the cross-sectional areas creating transition zones, successfully redirecting airflow and preventing recirculation. Despite these enhancements, airflow remained non-uniform at certain wind angles, indicating the need for further refinements. The WWC system offers a practical and scalable solution for multi-story building ventilation, particularly in retrofit applications where internal modifications are limited. Due to its modular design, the WWC system can be installed with minimal disruption, making it well-suited for integration into both new buildings and retrofit projects.

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Wang, C., Xu, J., Huo, Y., Guo, H.

Numerical study of the exposure to volatile organic compounds released from liquid crystal displays in an office.

Indoor and Built Environment, (2025)

People spend about 90% of their time indoors and indoor volatile organic compounds (VOCs) are critical to human health. Liquid crystal displays (LCDs) widely used in offices are a new source of indoor VOCs, with an emission rate of 8.25???109?molecules?s?1?cm?2 reported by Liu and Abbatt (2021). Therefore, this work studied the exposure to LCD VOCs in a four-person office environment through numerical simulation. Air change rate per hour (ACH), geometric setting and partition were also investigated. The results revealed that at an ACH of 4, human users inhaled 0.07%?0.25% of the released VOCs. The deviations for different users were 4?9 times due to various locations. Different geometric settings resulted in 2?3 times exposure deviations. Increasing the ACH to 20 led to an 88% reduction. The estimated lifetime exposure via inhalation was 8.2???1018 VOC molecules or 1?mg per LCD. This study contributed to the understanding of exposure to VOCs from LCDs.

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Vake, D., Hrovatin, N., Vičič, J., Tošić, A.

Occupancy estimation using indoor air quality data: opportunities and privacy implications.

Energy and Buildings, Vol. **343**, (2025)

Indoor Air Quality (IAQ) has long been a significant concern due to its health-related risks and potential benefits. Readily available air quality sensors are now affordable and have been installed in many buildings with public buildings taking center stage. The dynamics of IAQ are commonly studied in relation to different materials used in construction, building design, room utility and effects on occupants. However, besides what the sensors were designed to measure, it is possible to infer other information. In this paper, we present a Machine Learning (ML) model that predicts the presence of people in the room with an accuracy

as high as 93 % and the exact number of occupants with 2.17 MAE. We validate our proposed approach in the use-case of an elementary school in Slovenia. In collaboration with the elementary school in Ajdovščina, 8 air quality sensors were placed in classrooms and air quality parameters (VOC, CO2, Temperature, and Humidity) were monitored for 6 months. During the monitoring period, school staff collected anonymous data about classroom occupancy. The indoor air quality data was paired with external weather data as well as occupancy to train the model. Moreover, we compare our approach with other commonly used ML approaches and provide results related to our use case. Finally, these results highlight the privacy concerns related to structural monitoring due to the established ability to infer potentially sensitive information.

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Ospina-Rojas, E., Botero-Valencia, J., Betancur-Vasquez, D., Pearce, J. M.

Open-source three-dimensional IoT anemometer for indoor air quality monitoring.

HardwareX, Vol. **23**, (2025)

Ventilation in an enclosed space can significantly influence people's comfort, health, and safety. Poor ventilation can generate temperatures dangerous to health or obstruct the dispersion of environmental pollutants, such as toxic gases or pollution. Measuring indoor environmental conditions can thus help improve the quality of the environment and protect people's health and comfort. This work proposes the design of an open-source anemometer to measure wind speed and direction in three dimensions. The purpose of this anemometer is to monitor wind conditions in enclosed spaces and environmental conditions related to air quality and temperature. The prototype uses an array of six unidirectional flow sensors, each pointing towards a different axis. Carbon dioxide (CO2), volatile organic compounds (VOC), temperature, humidity, pressure, and gas presence sensors are integrated to monitor indoor environmental conditions accurately. Measuring the vertical component of the wind provides more detailed information on wind conditions. Test results show that the device can detect variations in wind speed with a deviation of 0.25 m/s, detect changes in horizontal wind direction with a deviation of 3.7°, and detect vertical wind direction variations with a deviation of 3.02°. These measurements demonstrate that the proposed device is capable of detecting wind changes in three dimensions, validating its potential for detailed indoor airflow monitoring.

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An, Y., Lei, Y., Pan, W., Wang, X.

Optimization and application of swirl ventilation systems based on orthogonal experiment design and response surface methodology.

Energy and Buildings, Vol. **345**, (2025)

The design and optimization of ventilation systems represent a critical challenge in building environmental control, as they are essential for maintaining indoor air quality and minimizing energy consumption. This study introduces a novel ventilation system utilizing partition devices to generate columnar swirling flow, aimed at enhancing indoor contaminant removal. Through a combination of scaled-down experimental models and numerical simulations, the effects of key parameters–including baffle width, air exhaust position, air exhaust dimensions, and airflow rate–on the contaminant removal efficiency (Ec) were systematically investigated. The results demonstrate that the system achieves optimal airflow velocity when the baffle width ratio (γ) is set to 1.0 and the air exhaust is positioned at the center of the local swirling ventilation zone induced by the baffles. Airflow rate was identified as the dominant factor influencing system performance, with higher rates significantly enhancing the negative pressure gradient. Furthermore, the application of this swirling ventilation mode was explored in industrial settings, where it exhibited remarkable improvements in contaminant removal efficiency. Specifically, under identical airflow rates, the local swirling ventilation system achieved a 1.83- to 16.73-fold increase in Ec compared to conventional ventilation systems. Notably, the general swirling ventilation system effectively eliminated heavy gaseous contaminants within 160 s. Compared to traditional general ventilation systems, which often exhibit poorly ventilated or stagnant regions, the proposed system demonstrated superior performance in pollutant

removal. These findings underscore the potential of swirling ventilation systems as a practical and efficient solution for indoor air quality management, particularly in industrial environments.

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Wong, S. J., Tan, H., Kek, H. Y., Othman, M. H. D., Woon, K. S., Wang, X.-C., *et al.*

Optimizing indoor air quality: evaluating the synergistic impact of filter integration and botanical solutions.

Clean Technologies and Environmental Policy, (2025)

Indoor air quality is crucial for human health and well-being, directly influencing respiratory function and overall comfort. Poor indoor air quality can lead to various health issues, including respiratory problems, allergies, and the exacerbation of pre-existing conditions, emphasizing the importance of maintaining a healthy indoor environment. This study aims to examine the synergistic impact of filter integration and botanical solution in enhancing air quality. A botanical indoor air biofilter (BIAB) rig that utilizes the low-cost Internet of things approach was developed. The air quality parameters are particulate matter 2.5 (PM2.5) and particulate matter 10 (PM10), volatile organic compounds (VOCs), carbon dioxide (CO2), air temperature, and relative humidity (RH). The smart sensors operated on RS485 Modbus protocol were integrated into the BIAB to monitor the real-time fluctuations of air quality parameters. A total of 5 combinations of parametric studies are tested, ranging from the usage of botanical plants, carbon filters, coconut husk, and granular activated carbon (GAC). These combinations were designed to assess the impact of different filtration configurations on the overall effectiveness of the system in reducing air pollutants. Results show that Case 3 (integrating botanical plants and a primary carbon filter) has the highest average reduction rate on PM2.5 with 5.36 µg/m3 per minute and VOCs with 4.13 µg/m3 per minute, respectively. However, Case 5 (integrating additional GAC) contributes to the highest reduction of PM10 concentration, with an average reduction rate of 5.23 ppm per minute.

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Shen, X., Sun, Q., Mosey, G., Cai, Y., Cheng, W.

Optimizing indoor air quality: The role of potted plants and machine learning models in reducing VOCs.

Urban Climate, Vol. **62**, (2025)

Indoor air quality become a significant public health concern, with volatile organic compounds (VOCs) causing various adverse health effects. Rapid urbanization, especially in regions with extreme temperatures, has increased reliance on mechanical ventilation, diminishing the effectiveness of natural ventilation in maintaining healthy indoor environments. The role of indoor potted plants in enhancing air quality is debated, as existing studies are mostly short-term and laboratory-based, leaving a gap in understanding their long-term efficacy and real-world applicability. Our study addresses this gap with a dual approach to mitigate VOCs in indoor environments. First, we developed an innovative, resource-efficient method to assess the VOC absorption capabilities of various plant species over extended periods, identifying robust candidates that sustain air quality improvements in real-world settings. Second, we employed machine learning algorithms to evaluate and predict VOC absorption behaviors, creating a scalable framework that assesses a broader range of plant species across diverse conditions without intensive experiments. Findings highlight the autumn fern as the most effective species in reducing VOCs over twelve days, with the maidenhair fern and Brazilian philodendron also showing significant potential. We also examined how environmental factors like light cycles and temperature variations impact VOC mitigation. Bidirectional Long Short-Term Memory (BiLSTM) networks demonstrated superior predictive accuracy and robustness. This research integrates plant-based solutions with advanced analytics, offering a comprehensive strategy to improve indoor air quality and promote healthier, more sustainable indoor environments.

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Souza, P. a. F., Crilley, L. R., Iranpour, Y. E., Dave, J., Vandenboer, T. C., Kahan, T. F.

Particulate Matter and Total Volatile Organic Compound Emissions Following Surface Cleaning: Comparison of Cleaning Agents and Locations.

ACS Earth and Space Chemistry, Vol. **9** n°(6), (2025), 1622-1632 p.

Cleaning activities are essential for maintaining hygiene in indoor environments but can significantly influence indoor air quality (IAQ). We investigated emissions of volatile organic compounds (VOCs) and particulate matter (PM) during cleaning events across various indoor settings including two laboratories, an office, and a residential bathroom, with room volumes ranging from 22 to 206 m3 and air changes rates (ACR) of 0.85–9.14 h-1. Four cleaning solutions with different active ingredients were evaluated: quaternary ammonium compounds (quats), hydrogen peroxide (H2O2), sodium hypochlorite (bleach), and thymol. Cleaning increased PM2.5 by 0.7–14.5 μg m–3, depending on location and cleaning solution, with quats generally yielding the greatest increases. Measured total volatile organic compound (TVOC) mixing ratios also increased following cleaning by 10–104 ppbv, with the exception of experiments performed using thymol. We note that sensors such as the photoionization detector (PID) used in this work do not provide quantitative TVOC measurements. In general, greater emissions of PM2.5 and TVOCs were observed in locations with lower ACR. We also measured PM2.5 in a lobby, elevator, and public bathroom in a hotel with a number of COVID-positive occupants during routine surface disinfection using a quats-based disinfectant: increases of 5.5–14.2 μg m–3 were observed. This study demonstrates that emissions other than active ingredients can affect IAQ during surface cleaning, and provides information that may help mitigate harmful effects. It also provides insight into the use and limitations of low-cost sensors (LCS) in determining IAQ impacts from cleaning.

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Sharma, R. K., Kumar, A., Rakshit, D.

Performance analysis of an HVAC system retrofitted with nano-enhanced phase change material-based heat exchanger.

Energy, Vol. **330**, (2025)

Incorporation of fresh air into a building through Heating, Ventilation, and Air conditioning (HVAC) systems improves indoor air quality; however, this poses a challenge as it increases the cooling load and increases the energy demand of the building. In the present study, an existing office in New Delhi, India, which is located in the composite climate zone, is analyzed for different factors contributing to cooling load. Further, a concentric tube type, phase change material (PCM) based heat exchanger is numerically modelled to reduce the energy consumption of a conventional HVAC system. The integration aims to extract the thermal energy from fresh air, ultimately reducing overall energy consumption. The PCM used is octadecane due to its proximity to human comfort range. The modified system reduced the cooling load due to higher temperature fresh air by 7.27 % and achieved an energy savings of 3.28 % over a conventional HVAC unit. The reduction in the fresh air cooling load and energy saving is further enhanced by the addition of CuO nanoparticles in PCM stored in the annulus of the heat exchanger. In addition, internal longitudinal fins are incorporated into the internal tube of the heat exchanger. It is found that with 24 internal fins and 1 % CuO nanoparticle, the cooling load and energy consumption can be reduced by 23.25 % and 7.81 %, respectively. The study offers policymakers sustainable and energy-efficient alternatives for HVAC systems, presenting viable solutions to diminish energy demand and contribute to the fight against climate change.

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Vaishnavi B; Meril Rohan C; Nikhil Kaarthik S S; Pranesh M

Performance Evaluation of an IoT-Integrated HEPA Air Purifier in High-Pollution Plastic Manufacturing Facilities.

2025 International Conference on Computational Innovations and Engineering Sustainability (ICCIES)

The plastic injection molding industry plays a vital role in modern manufacturing, producing a wide range of consumer and industrial goods. However, it generates significant indoor air pollution, including particulate matter (PM2.5, PM10) and harmful gases such as carbon monoxide and sulfur dioxide. These emissions, resulting from high-temperature processes, pose serious health risks to workers, leading to respiratory and cardiovascular ailments, reduced productivity, and compromised workplace safety. This emphasizes the need for customized air purification systems in high-pollution industries like plastic manufacturing sectors. These systems not only improve air quality but also protect worker health, enhance productivity, and ensure regulatory compliance. This study evaluates the performance of a custom-designed industrial-grade High-Efficiency Particulate Air purifier integrated with Internet of Things based monitoring in addressing indoor air pollution within a plastic manufacturing facility. Unlike conventional systems, this advanced solution aids in real-time monitoring, performance optimization, and predictive maintenance contributing to a safer and a more sustainable work environment.

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Liu, Z., Cheng, L., Yin, X., Francis, M.

Pollutant dispersion characteristics under hybrid natural ventilation with mechanical exhaust in industrial buildings: Effect of initial source release settings.

International Journal of Heat and Fluid Flow, Vol. **116**, (2025)

Poor ventilation usually leads to the inability to timely eliminate many toxic and harmful gases in industrial buildings, which has a negative impact on the health of occupant workers. Ventilation not only improves working environment, but also increases personnel work efficiency, which is of great significance for creating a productive environment in industrial buildings. Although researchers have conducted a large amount of investigations on ventilation in industrial plants, there is a paucity of studies on the effect of the initial source release condition on pollutant dispersion performance. In this study, the dispersion characteristics of harmful gas hydrogen sulfide H2S, typical in industrial plants, were numerically simulated under hybrid induced ventilation with mechanical exhaust. A scaled model test was designed and carried out using working medium sulfur hexafluoride SF6, and the test data was utilized to validate the numerical model. The influence of the initial settings of pollutant release sources, including the temperature of release source, opening ratio of release source and the intermittent release of pollutant source on H2S dispersion, velocity and temperature distribution, and concentration distribution was analyzed. The pollutant removal efficiency was adopted to evaluate the ventilation performance. Some valuable findings were obtained. This study is significant to further understand the dispersion mechanism of H2S in rubber processing workshops and can supply a technique reference for the ventilation system design in associated industrial buildings.

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Kataria, A., Mishra, J. K., Aras, A., Kumar, S.

A Pragmatic Approach Toward Enhancing Indoor Air Quality in Urban Settings With Limited Ventilation.

IEEE Sensors Journal, Vol. **25** n°(11), (2025), 20602-20609 p.

The endeavor of furnishing active indoor air purification in urban settings, characterized by low complexity and real-time operation, is challenging, attributable to the requirement of actively eliminating total volatile organic compounds (TVOCs). In metropolitan regions with a dearth of natural light and airflow, the internal atmosphere may rapidly amass TVOCs, which can create serious negative impacts on human health. To tackle this predicament and advocate for salubrious living, the Internet of Things (IoT) arrangement enabling real-time monitoring of indoor TVOC levels with a cloud-based sensor system and the automated reduction of TVOCs by autonomously operated ionizers is demonstrated. The system is installed and tested on TVOCs common in everyday life in a controlled environment that represents real-life climate-controlled indoor spaces, including realities like leakages in the air-conditioning systems. The investigations derived from calibrated real-time monitoring sensor measurements and subsequent analysis reveal that the proposed closed-loop ionizer system is effective in reducing the harmful TVOC levels by more than 20%

with one ionizer and more than 70% with two ionizers in a realistic indoor environment. The results also clearly establish that this system is scalable, as higher ion concentration boosts the suppression of the TVOCs. This proposed method thus clearly establishes an effective way of improving air quality by reducing TVOCs that is progressive and practical to apply in real-life dwellings to improve the well-being of the inhabitants.

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Dheer, I., Mehta, S., Somanchi, S., Nelson, A., Srivastava, A.

Predeployment Calibration Framework for Low-Cost Gas Sensors: An Adaptive Environmental Parameter Model.

IEEE Sensors Letters, Vol. **9** n°(7), (2025), 1-4 p.

Reliable toxic gas detection is vital for residential and industrial safety. While precise sensors are expensive, affordable ones face challenges of nonlinearity and environmental sensitivity, particularly from temperature (T) and humidity (H) effects. In this work, we present a novel predeployment calibration framework that accounts for these environmental factors on the sensor behavior, given by the resistance ratio (Rs/Ro) at constant gas concentration levels. The proposed method first refines the baseline resistance (Rs) estimation by fitting a power-law model to known gas concentrations and then applies a cubic regression model to capture the nonlinear effects of temperature and humidity on the Rs/Ro ratio. Cubic regression achieves superior accuracy (>5.8%) over lower order models while reducing over-fitting risks compared to higher order polynomials. It achieves 99.65% average accuracy, outperforming the 96.73% from standard libraries. This improved performance is particularly notable at low ppm levels, where direct Rs measurements are typically noisy and unstable. The enhanced stability and accuracy of the proposed method were validated over a continuous 90-min test period.

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Zheng, Y., Xu, X.

Predicting indoor 3D high-resolution airflow distribution with unknown air supply inlet and occupant locations using ANN.

Energy and Buildings, Vol. **344**, (2025)

Fast and accurate models for predicting indoor 3D high-resolution airflow distributions can be integrated with Heating, Ventilation and Air Conditioning (HVAC) systems to regulate indoor environments for occupant thermal comfort. Artificial Neural Network (ANN) is a mathematical model that can establish mapping relationships between variables with non-linear relationships. This study aims to develop an ANN-based method to predict indoor 3D high-resolution airflow velocity and temperature distributions corresponding to unknown air supply parameters and room layouts. A cascaded architecture consisting of a velocity prediction model and a temperature prediction model was designed. The air supply velocity, direction, angle, air inlet and occupant location are integrated as 3D inputs representing the initial room state. The velocity prediction model predicts the airflow velocity distribution near the occupant, and the temperature prediction model, in addition to the aforementioned parameters, also uses the velocity distribution, air supply temperature, and heat production rate as inputs to predict the temperature distribution. The model performed well, effectively reducing the training difficulty and demonstrating better generalizability compared to other models. The prediction times for the velocity and temperature distributions are 10.80 s and 0.28 s, respectively, which support real-time integration with HVAC control systems.

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Ibna Ali, A. R., Liang, R. L. F., Mohee, F. M., Freire-Gormaly, M.

Quantification of the spatiotemporal heterogenous infection risk associated with respiratory virus-laden aerosols in an aircraft cabin in the context of airborne contagious diseases.

Journal of Aerosol Science, Vol. **189**, (2025)

A single-aisle aircraft cabin was investigated to quantify the infection risk by utilizing a spatiotemporal model for MV, DV, and DV with extra outlets. The ventilation effectiveness was also assessed. The HRE of the DV system was 68.9 % higher compared to the MV system. PD for MV configuration was lower compared to DV with a range of 0.34 %–6.75 %. On average, the DR for MV was found to be about 3.98 %, while for DV configuration, it was found to be approximately 2.59 %. The position of the index passenger impacts the dispersion of aerosols in the cabin, leading to varied infection risk levels throughout the cabin. The seat nearest to the index person in the same row possesses the highest risk of infection both from near-wall and near-aisle coughing in the MV configuration, as well as near-wall coughing in the DV configuration. However, the seat closest to the aisle in the same row had the highest risk of exposure to risk from near-aisle coughing in a DV configuration. Highly infectious zones were located in the same row seated with the index person and the back from the index person for MV near-wall and near-aisle injections. For the near-aisle coughing in the DV system, the risk was negligible for the first two columns containing the index passenger. Lower infection risk with higher HRE and dissatisfaction was found with DV configuration for the susceptible passengers. Wearing a highly efficient mask, such as an N95, significantly reduces the risk of infection in all cases.

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Odum, H., Oram, S.

Redesigning Past for Future: Electrification and DOAS for Resiliency and Efficiency.

ASHRAE Journal, Vol. **67** n°(6), (2025), 66-67 p.

The 2020–2022 renovation of the 1910 Portland Galleria building incorporates four stories of offices over ground floor retail as a tale of two parts. First is core & shell renovation, focusing on historic preservation, embodied carbon savings and deep green energy conservation via elimination of fossil-gas and decentralized HVAC design. Second is a tenant improvement (TI) project to transform the 3,716 m2 (40,000 ft2) top floor into an example of an adaptable and resilient office space through dedicated outdoor air systems (DOAS) and advanced central controls.

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Zhang, F., Shan, K., Wang, S.

Risk assessment-based particle sensor location optimization for non-unidirectional cleanrooms concerning air distribution uncertainties.

Building and Environment, Vol. **276**, (2025)

Air conditioning systems in cleanrooms require a huge amount of clean air to maintain the desired indoor air cleanliness, resulting in significant energy consumption. A major challenge in achieving energy-efficient control of such systems is obtaining accurate and reliable measurements of particle concentration which is essential for precisely controlling minimum but sufficient airflow rate. Therefore, this paper proposes a risk assessment-based method for optimizing particle sensor locations in non-unidirectional cleanrooms, addressing the limitations of conventional empirical methods for sensor placement. Two sensor performance indexes, "systematic measurement bias" and "spatial violation risk", are formulated to balance measurement accuracy and the risk of unsatisfactory air cleanliness at a sensor location. This optimization method is explored through experimentally validated computational fluid dynamics simulations based on a typical non-unidirectional cleanroom. The results show that the proposed method can be conveniently implemented to optimize the sensor location under various scenarios, and improve the particle monitoring performance by optimizing the number of sensors and the location of source. Compared to a commonly-used practical sensor placement method, the proposed method can reduce the spatial violation risk by 31 %.

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Budde, M.

Sensors for Air Quality Monitoring.

MDPI-Multidisciplinary Digital Publishing Institute; 2025

Novel sensors to detect air pollutants like fine dust (PM10, PM2.5), O3, NO2, NO, or CO, as well as greenhouse gases like CO2, are currently available and have been widely used for atmospheric and indoor air monitoring. Although these sensors are small, lightweight, fast, and cheap, they can be relatively unstable and inaccurate. To address these limitations, further research is needed in the following areas: possibilities and shortcomings of new sensing techniques and applications; methodologies to overcome their disadvantages; solutions to integrate networks of these sensors into existing, well-calibrated air quality monitoring networks; solutions to use them for air quality monitoring; and their application in new tasks such as the detection of air pollution hot spots or the evaluation of emission inventories and numerical air pollution simulations. Environmental scientists, including physicians, chemists, and epidemiologists, play a vital role in defining the requirements for developing new sensors to detect harmful compounds in the atmosphere. The detection of personal air pollution exposure, and potentially personal pollen and fungi exposure in the future, is close to being elucidated and will form the basis for enhanced measures to improve human health.

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Zhao, Y.-B., Chen, T.-L., Wang, J.

Size-dependent airborne metal solubility and associated analytical techniques at bulk and single particle levels: A review.

Atmospheric Environment, Vol. **358**, (2025)

Size-dependent airborne metal solubility in air and living organisms has been identified as a key parameter to understanding aerosol-cloud interactions, global biogeochemical cycles, indoor air quality, and aerosol toxicity. Emission sources play a dominant role in size-dependent airborne metal solubility, which could be enhanced by atmospheric aging. Studies show that toxic metals (e.g., heavy metals) concentrated in submicron particles tend to have a higher solubility compared to crustal metals and possess even higher solubility levels in biological fluids than those in water, which may trigger more adverse health effects. Factors related to metal solubility and particle size, such as liquid water concentrations and acidity levels, mixing states, and particle parameters of particles, were discussed. Analytical techniques on various scales play an essential role in accurately measuring size-dependent metal solubility, particularly for soluble fractions. Available detection techniques at bulk and single particle levels were examined, including offline, online, and mapping analysis. The purpose of this overview is to summarize the current understanding of size-dependent airborne metal solubility and related state-of-the-art analytical techniques. We also identified future challenges and provided perspectives for studies of size-dependent metal solubility and the development of associated analytical techniques.

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Taamte, J. M., Flore, T. S. Y., Nasser, N., Susan, Y.-N. Y., Gouroudja, A., Claude, E. E. R., *et al.*

Smart electronic device for air quality and exposure risk assessment.

Smart Science, Vol., (2025), 1-15 p.

This article reports on the measurement of air pollutants and assessment of health exposure risks in two reference hospitals in the city of Yaoundé, using a locally manufactured smart electronic device for the measurement of highly toxic air pollutants. This low-cost device is based on an Atmega328 microcontroller, toxic gas sensors (O3, PM2.5, CO, CO2 and NO2), temperature (T), relative humidity (RH) sensors, and XBee modules to establish the Internet of Things (IoT). In each of the two hospitals, 2 weeks of measurements conducted from October 15 to 30, 2023 at Biyem-assi Hospital and from September 1 to 15, 2023 at Central Hospital. The average values obtained were 0.96 ± 0.06 ppm and 0.37 ± 0.09 ppm for O3, 39.66 ± 10 µg/m3 and 39.72 ± 10 µg/m3 for PM2.5, 0.41 ± 0.01 ppm and 0.42 ± 0.02 ppm for CO, 316.55 ± 63 ppm and 305.84 ± 89 ppm for CO2, and 0.43 ± 0.01 ppm and 0.45 ± 0,02 ppm for NO2 in

Biyem-assi and Central Hospitals, respectively. These values were used to assess the risk of exposure through the Air Quality Index (AQI) and the Air Quality Health Index (AQHI2.5).

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Davis, T.

Spring Into Safety: How Seasonal Deep Cleaning Strengthens Hospital Infection Control.

Infection Control Today, Vol. **29** n°(3), (2025)

Rooted in ancient rituals of renewal, spring-cleaning has evolved from cultural tradition to a vital infection prevention strategy in modern hospitals—one that blends seasonal deep cleaning with advanced disinfection to reduce pathogens, improve air quality, and protect patients.

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Li, C., Wang, H., Zeng, X., Li, X., Jin, R., Chi, Y.*, et al.*

Strategies for enhancing performance sustainability of air filters: challenges and future directions.

Separation and Purification Technology, Vol. **376**, (2025)

The escalating challenges of air pollution and health issues in indoor environments have underscored the critical role of air filters in improving indoor air quality. However, traditional air filters face an inherent trade-off among filtration efficiency, airflow resistance, and service life. Specifically, highly efficient filters tend to exhibit a high pressure drop and shorter service life, resulting in increased energy consumption and more frequent maintenance. These limitations pose significant barriers to the development of high-performance and long-life air purification systems. This review aims to explore multidimensional solutions for enhancing the performance sustainability of air filters. Through a systematic review of recent advancements, this study focuses on four key areas: structural optimisation, material innovation, electrostatic enhancement, and cleaning and regeneration technologies. A comprehensive analysis is provided on the contributions of these technologies to improving filtration efficiency, reducing energy consumption, and extending filter longevity. Finally, this review integrates insights across these domains to propose a multidimensional strategy for the advancement of air filtration technologies. It establishes a clear foundation for the development of sustainable, high-performance filtration systems, thereby contributing significantly to the green transformation of the built environment and the protection of public health.

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Leprince, V., Hurel, N., Janssens, A.

Trends in building and ductwork airtightness in 16 countries.

14th International BUILDAIR Symposium, 16-17 May 2025, Hannover, Germany

This work presents an overview and comparison of building and ductwork airtightness trends across 16 countries. It focuses on the national regulations, requirements, and drivers promoting airtightness in buildings and ductwork, and how airtightness is included in energy performance calculations.

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