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

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Google Scholar, Lens, WoS

Zhou, X., Fang, W., Dong, X., Li, W., Liu, J., Wang, X.

Advancing characterization of VOC diffusion in indoor fabrics: A dual-porosity modeling approach.

Environmental Pollution, Vol. **363**, (2024)

Volatile organic compounds (VOCs) are major chemical pollutants in indoor air. Indoor fabrics, such as curtains, carpets, sofas, and clothes, strongly adsorb VOCs due to their high loading rates and large specific surface areas. The desorption of VOCs from these fabrics can act as a secondary source, worsening indoor air pollution and prolonging its effects. The diffusion coefficient is a key parameter that determines the source-sink properties of fabrics. In this study, the VOC diffusion characteristics in fabrics were investigated through microstructural examination, mass transfer analysis, and environmental chamber experiments. Yarn and fiber gaps were identified as dual mass transfer channels within the fabrics and were represented using two distinct fractal models. A dual-porosity medium (DPM) model, based on these fractal representations, was developed to predict the VOC diffusion coefficients in indoor fabrics and was validated via experiments under various environmental conditions and fabric-VOC combinations. The results highlight the significant impact of fabric structure and composition on VOC adsorption and emission dynamics. The validated DPM model provides a comprehensive approach to predicting VOC diffusion in fabrics, providing a more accurate method for assessing indoor air quality and fabric-mediated human exposure.

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Marques, R., Gonçalves, C., Ferreira, R.

Airsense – Low-Cost Indoor Air Quality Monitoring Wireless System.

New Trends in Disruptive Technologies, Tech Ethics, and Artificial Intelligence. The DITTET 2024 Collection

This manuscript presents the project aimed at creating a low-cost indoor air quality monitoring system. By using a variety of sensors connected to an ESP32 microcontroller, the system measures specific parameters such as carbon dioxide, volatile organic compounds, particulate matter, temperature, humidity, and pressure. The sensor-recorded measurements are sent to an InfluxDB database via Wi-Fi, where they are accessed by Grafana, which generates a graphical user interface that displays the evolution of all collected data. The values can be visualized in various graphical styles according to the user's preference, including tables, time-series charts, and histograms. Initially, some research was conducted to evaluate various types of microcontrollers and sensors to select the best options based on factors such as cost, size, and measurement accuracy. A printed circuit board and a 3D-printed enclosure were designed alongside the final prototype, which facilitated the integration of the various hardware components. Lastly, a two week-long test was conducted, in a school environment, using the final hardware to validate the overall results and operating behavior of the developed system.

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Ramohlokoane, M. M., Awuzie, B. O., Ramantswana, T.

Appraising the Influence of Individual Workspace Preferences on the Perceived Productivity and Wellbeing of Employees: A Scoping Review.

Transdisciplinary Workplace Research. 4th-7 th September 2024. Edinburgh Napier University

Workspaces should provide a sense of comfort and positive wellbeing as workers spend a large amount of time there. Also, productivity can be affected by a number of varying working conditions and indoor environment quality (IEQ) levels. Such working conditions include abuse of power in assigned roles, gross mismanagement, increased overtime working and noise levels, while IEQrelated factors comprise of acoustic comfort, indoor air quality, interior designs, thermal comfort, and visual comfort. The persistence of these conditions has been largely attributed to nature of the physical workspace environment. Considering the plethora of workspace environments in existence it is believed that employees would prefer certain workspace environments. Impliedly, understanding employees' preferred workspace environments would contribute positively to their productivity and wellbeing. Therefore, it has become imperative to determine this nexus as it would facilitate the development of a mechanism for effective workspace allocation in corporate organizational settings. However, studies seeking to achieve this objective remain scant. This is the gap that this study seeks to address. The aim of this study is to determine if an individual's preference for certain workspace environments can influence his/her perceived levels productivity and wellbeing. This paper relied on the principle of the person-environment fit theory to explore the alignment between individual preferences and the surrounding environment. The study employs a 434 scoping review methodology for data collection. The selected papers were thoroughly analysed to provide an overview of findings and research gaps. The study found that by incorporating individual traits and demographic information allows for creating workspaces which are highly productive and contribute positively to wellbeing. The findings contribute towards developing a framework for understanding how employee workspace design preferences affect productivity and wellbeing from an individual prospect.

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Yefi, P., Ejaz, S., Menon, R. P., Eicker, U., Guéhéneuc, Y. G.

An Architectural Approach for Enhanced Data Interoperability Across Building Systems.

2024 7th Conference on Cloud and Internet of Things (CIoT). 29-31 Oct. 2024. Montreal, QC, Canada

Access to building data is crucial for creating portable applications and improving building operation and energy efficiency. Ensuring data transmutability is essential for facilitating research and overcoming the diverse data representation, management, and collection methods across various building management systems (BMSs). Different BMSs use multiple interfaces for data exchange. Some BMSs provide Application Programming Interfaces (APIs) for data exchanges, while others have gateways connecting to cloud services for application subscription and data access. This study introduces a five-layered architecture that describes how client applications, researchers, and other interested stakeholders can exchange data with different BMSs.

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Agarwal, D., Trinh, X. T., Takeuchi, W.

Assessing the Air Quality Impact of Train Operation at Tokyo Metro Shibuya Station from Portable Sensor Data.

Preprints, (2024)

Air pollution remains a critical global health concern, with 91% of the world's population exposed to air quality exceeding World Health Organization (WHO) standards and indoor pollution causing approximately 3.8 million deaths annually due to incomplete fuel combustion. Subways, as major public transportation modes in densely populated cities, can exhibit fine particulate matter (PM) levels that surpass safety limits, even in developed countries. Contributing factors include station location, ambient air quality, train frequency, ventilation efficiency, braking systems, tunnel structure, and electrical components. While elevated PM levels in underground platforms are recognized, the vertical and horizontal variations within stations are not well understood. This study examines the vertical and horizontal distribution of $PM_{2.5}$ and PM_{10} levels at Shibuya Station, a structurally complex hub in the Tokyo Subway System. Portable sensors were employed to measure PM concentrations across different platform levels—both above and underground—and at various locations along the platforms. The results indicate that above-ground

platforms have significantly lower $PM_{2.5}$ and PM_{10} levels compared to underground platforms (17.09 µg/m³ vs. 22.73 µg/m³ for $PM_{2.5}$; 39.54 µg/m³ vs. 56.98 µg/m³ for PM_{10}). Notably, the highest pollution levels were found not at the deepest platform but at the one with the least effective ventilation. On the same platform, PM levels varied by up to 63.72% for $PM_{2.5}$ and 120.23% for PM_{10}, with elevated concentrations near the platform extremities compared to central areas. These findings suggest that ventilation efficiency plays a more significant role than elevation in vertical PM variation, while horizontal differences are likely influenced by piston effects from moving trains. The study underscores the risk of exposure to unsafe $PM_{2.5}$ levels in underground platforms, particularly at platform extremities, highlighting the need for improved ventilation strategies to enhance air quality in subway environments.

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Decilap, D., Guyot, G., Besombes, J.-L., Golly, B.

Assessment of the indoor/outdoor dynamic of some air pollutants in three buildings located in the valley city of Chambéry, France.

44th AIVC -12th TightVent & 10th venticool Conference, AIVC, Oct 2024, Dublin, Ireland

In recent years, population exposure to air pollution has been a major concern. Indoor air quality (IAQ) is mainly monitored with CO2-concentration-based indicators. High levels of CO2- concentration are avoided in buildings when airing by the windows is done and/or when air exchange rate of the existing ventilation is regulated, based on a CO2-level-information. However, as contributing to maintain low CO2-concentration-levels indoors, the increase of outdoor air intake is associated with a more or less important introduction of outdoor air pollutants in the building. Among these pollutants, there are particulate pollutants as PM2.5 and there is NO2 that is a gaseous pollutant mainly emitted by the road-traffic. Many previous papers dealt with the indoor/outdoor dynamics. However, only rare studies, like Bucur et Danet (2019), Bi et al. (2021) or Nezis et al. (2022), were based on outdoor air measurements up to 500 m away from the studied buildings. The aim of this study is to evaluate such dynamics for PM2.5 and NO2. It was based on a twomonths measurements campaign in three buildings presenting different ventilation types. In addition to the reference data of the local air quality monitoring station, an optical particles measurement was introduced on the façade of the buildings.

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Isman, N. I. I., Jalaludin, J., Suhaimi, N. F., Hashim, F., Tualeka, A. R.

Association between indoor air quality and sick building syndrome among workers in food outlets in Selangor, Malaysia.

Journal of Environmental Health, Vol. **16** n°(4), (2024)

Introduction: Indoor air pollution, causing health issues like Sick Building Syndrome (SBS), is the third largest global contributor to disability-adjusted life years, emphasizing the urgent need for improved indoor air quality. This study aimed to determine the association between Indoor Air Quality (IAQ) and SBS among workers at food outlets in Selangor, Malaysia. **Methods:** A cross-sectional study was carried out among 107 workers in mall, new and old food outlet. A set of standardized and validated version questionnaires of the Industry Code of Practice on Indoor Air Quality (ICOP IAQ) 2010 was distributed to obtain respondents' sociodemographic information, symptoms present at the workplace, and psychosocial information. **Results and Discussion:** The study found significant differences in temperature (p = 0.004), air velocity (p = 0.037), ultrafine particles (p = 0.005), and carbon dioxide (CO2) concentrations (p = 0.006) in malls, new and old food outlets. Workers in old food outlets had the highest prevalence of SBS (66.7%), compared to those in new outlets (60.5%) and mall outlets (64.7%). Environmental characteristics, such as increased dust and particulate matter during renovation (OR = 6.17, 95% CI = 1.34-28.34), repair (OR = 2.43, 95% CI = 1.03-5.76), along with temperature variations (OR = 7.21, 95% CI = 2.52-20.66) significantly influencing SBS. **Conclusion:** SBS prevalence in food outlets is not significantly linked to IAQ parameters, but exposure to UFP and PM2.5 may contribute to its development. However, it is significantly associated with workplace renovations and repairs for interior design, as well as varying temperatures.

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Lara-Calle, A., Molina, W., Escudero-Villa, P.

Automated AirWellness System.

2024 IEEE Eighth Ecuador Technical Chapters Meeting (ETCM). 15-18 Oct. 2024

Many Latin American countries face indoor air quality issues due to rapid urban growth, industrialization, and the lack of environmental regulations. Companies must ensure safe work environments in Tungurahua, Ecuador, especially concerning air quality. Exposure to CO,NOx,SO2, and particulate matter (PM) can lead to respiratory illnesses. This project focuses on mitigating air pollution in indoor spaces of companies in Tungurahua through an automated purification system using IoT. Employing automated measurement technology, the system identifies and manages chemical and ergonomic risks. An activated carbon-based purification system optimizes the reduction of pollutants, while IoT integration allows for real-time monitoring and automatic activation of the cleaner. The system's validation was performed by quantifying alcohol (2000mg/m3), carbon monoxide (100 ppm), carbon dioxide (200 ppm), and PM2.5 particles (2500ug/m3). A statistical analysis using the Wilcoxon test showed a significant difference between the values before and after using the purifier, with a p-value less than 0.05, allowing the rejection of the null hypothesis and acceptance of the alternative. The results indicate a significant reduction in pollution levels. This prototype can improve air quality in indoor spaces, promoting respiratory health among workers and providing a foundation for the development of future risk prevention systems.

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Dam-Krogh, E. P.

Benchmarking the Indoor Environment in Office Buildings: Characterisiation, Synthesis and Practical Application.

Technical University of Denmark. Thèse 2024

This study presents a comprehensive investigation of indoor environmental quality and its impact on occupant health, well-being, and productivity in office buildings across Denmark and Greenland. Through the establishment of a robust database and the development of a novel benchmarking tool, the research aims to facilitate the evaluation of building and workplace performance, while estimating potential value gains from improving indoor conditions.

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Yang, Z., Liu, Y., Chen, M., Xiang, M., Gao, G., Cui, D.*, et al.*

A breathable, waterproof and battery-free wearable e-nose with high flexibility based on MEMS gas sensors for accurate identification of volatile aromatic hydrocarbons.

Applied Materials Today, Vol. **42**, (2025)

Benzene, toluene, ethylbenzene, xylene, and styrene (BTEXS) are harmful gases indoors and in the cabin. Electronic nose (e-nose) technology has shown great potential in detecting BTEXS. However, to maintain the normal operation of the e-nose and improve the recognition accuracy, it often employs a large array of metal oxide semiconductor (MOS) gas sensors, along with extensive signal processing circuits and high-power solid-state batteries. The bulky structure makes it difficult for the e-nose to realize the portable real-time detection of BTEXS. Herein, a breathable, waterproof, battery-free, and highly flexible wearable e-nose (BWBFW e-nose) is fabricated for BTEXS detections. In detail, we first prepare a combination scheme of n-type and p-type MOS for forming four MEMS gas sensors, exhibiting differentiated response characteristics. Subsequently, a wireless supply module and a wireless signal processing module are designed on a flexible porous circuit board. Then, a waterproof and breathable membrane by electrospinning was adopted to encapsulate the flexible circuit board, endowing the e-nose with high safety. Finally, accurate identification and low-error concentration prediction of BTEXS are achieved with the help

of a 1D Convolutional Neural Network (1DCNN) algorithm. We believe the e-nose reported here will shed new light on the design of new devices for detecting BTEXS.

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Guo, X.

Chemical Characterization of Indoor Air Pollutants: Implications to Consumer and Occupational Health.

University of Alberta. Thèse 2024

Humans living in the contemporary societies find the majority of their time spent indoors, promoting awareness regarding indoor air quality over the past decades. The indoor environment has gained significant complicity due to an increasing variety of

inhalable products consumed in our daily lives. Many indoor chemistry processes have not been fully characterized; hence chemical pollutants produced from these processes are under-discovered. In particular, our exposure to air pollutants in residential and occupational settings could be vastly different from the typical indoor environment. This is because chemicals involved in these scenarios are product- and occupation-dependent. One can receive immense exposure to specific chemicals that are uncommon in normal settings. However, very limited research has been done to investigate chemical pollutants involved in consumer and occupational settings. At the same time, it is always challenging to conduct representative studies on this topic due to the high diversity of indoor environments. Hence, fundamental studies on indoor chemistry processes are needed to address this problem.

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Caglayan, I., Afacan, Y.

Clustering-based agent system (CAS) to simulate the energy-related behaviours of office occupants.

Architectural Science Review, Vol., (2024), 1-15 p.

Rapid urbanization and building sector growth emphasize the critical role of energy conservation in addressing global energy consumption and greenhouse emissions. Despite advancements in energy-efficient technologies, an ?energy performance gap? exists between predicted and actual energy use, significantly influenced by occupant behaviour. This study explores energy-related behaviour in office buildings by integrating existing behavioural theories including the Theory of Planned Behaviour and the Self-determination Theory, and construct of habit and comfort. Data from an online survey were analyzed using principal component analysis, two-step cluster analysis, and descriptive statistics, identifying three behavioral clusters: ?Cautious Saver?, ?Compelling Dissatisfied?, and ?Coherent Potent?. These clusters represent distinct energy-related behaviours. A Clustering-based Agent System (CAS) was then proposed to simulate the energy-related behaviours of these clusters, offering a dynamic and adaptive modelling framework. The study advocates for a comprehensive approach, integrating behavioural theories to provide insights for developing accurate occupant behaviour models.

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Furst, L., Cipoli, Y., Galindo, N., Yubero, E., Viegas, C., Pena, P.*, et al.*

Comprehensive analysis of particulate matter, gaseous pollutants, and microbiological contamination in an international chain supermarket.

Environmental Pollution, Vol. **363**, (2024)

Indoor environmental quality is of utmost importance since urban populations spend a large proportion of their life in confined spaces. Supermarkets offer a wide range of products and services that are prone to emitting several air pollutants. This study aimed to perform a comprehensive characterisation of the indoor

and outdoor air quality in a multinational supermarket, encompassing not only criteria parameters but also unregulated pollutants of concern. Monitoring included measurements of comfort parameters, CO2, multiple gaseous pollutants, particulate matter (PM10) and bioburden. PM10, volatile organic compounds (VOCs) and carbonyls were subject to chemical speciation. Globally, the supermarket presented CO2, VOCs, and PM10 values below the limits imposed by international regulations. The PM10 concentration in the supermarket was 33.5 ± 23.2 µg/m3, and the indoor-to-outdoor PM10 ratio was 1.76. Carbonaceous constituents represented PM10 mass fractions of 21.6% indoors and 15.3% outdoors. Due to the use of stainless-steel utensils, flour and fermentation processes, the bakery proved to be a pollution hotspot, presenting the highest concentrations of PM10 (73.1 ± 9.16 µg/m3), PM10-bound elements (S, Cl, K, Ca, Ti, and Cr) and acetaldehyde (42.7 µg/m3). The maximum tetrachloroethylene level (130 µg/m3) was obtained in the cleaning products section. The highest values of colony-forming units of bacteria and fungi were recorded in the bakery, and fruit and vegetable section. The most prevalent fungal species was Penicillium sp., corresponding to 56.9% of the total colonies. In addition, other fungal species/sections with toxicological or pathogenic potential were detected (Aspergillus sections Aspergilli, Circumdati, Flavi, Mucor and Fusarium sp.).

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Wang, Z., Zhang, X., Wang, L., Fu, S., Wu, J., Xiong, J.*, et al.*

Concentrations and short-term health effects of VOCs in explored subway, bus and taxi in Beijing, China.

Atmospheric Environment, Vol. **339**, (2024)

The transportation environment is one we are exposed to every day. However, previous research on exposure to volatile organic compounds (VOCs) and their acute health effects in various public transportation is limited. To address this gap, we conducted a panel study involving 25 healthy adults, investigating the exposures and acute health effects of exposures to 24 VOC species during 40-min commutes in Beijing's subways, buses and taxis during early spring 2023. Our findings revealed that exposure to multiple VOC species, including toluene, styrene, tetrachloroethylene, ethylacetate, resulted in a decrease in Heart Rate Variability (HRV). Specifically, SDNN decreased by 4.37 ms (95%CI: −8.52, −0.21) with per interquartile range (IQR) increase in ethylacetate; rMSSD decreased by 9.93 ms (95%CI: −19.01, −0.86), 4.75 ms (95%CI: −8.63, −0.86), and 7.00 ms (95%CI: −13.20, −0.81) with per IQR increase in toluene, styrene, and tetrachloroethylene, respectively; HF decreased by 154.07 ms2 (95%CI: −284.03, −24.11) with per IQR increase in carbon tetrachloride. For joint effect of these VOC species, we found significant associations with HRV only in taxis. Moreover, higher cyclohexane and methylcyclohexane exposures were linked to reports of sick car syndrome. Despite wearing masks during the COVID-19 period, comparative results from a supplementary experiment conducted post-COVID-19 without masks indicated that masks may not significantly reduce the adverse effects of VOC exposure. Our findings indicated the potential acute health risks of short-term VOC exposures in public transportation, particularly in taxis, highlighting the necessity to improve air quality and related standards in these micro-environments.

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Akıner, İ., Akıner, M. E.

The Concept of Healthy Building and Factors Affecting Sick Building Syndrome in Dwellings.

ICONSR 2024. 7th International Conference on Social Science Research. Durres Albania. October 2024

Considering that people spend 90% of their time indoors, the indoor environment is by far the most important environment for human health in the modern world. It is thought that indoor environments are linked to numerous ailments related to indoor air quality, including lung cancer, allergies, and airborne infections. The risk of illnesses linked to indoor air quality is, nevertheless, understood to be relatively low in the "Healthy Building" concept if there is no moisture issue endangering the building and all indoor spaces-including wet areas-are suitably ventilated. Numerous scientific investigations show that potentially dangerous compounds known as indoor air pollutants are emitted by various building materials and harm

the interior environment's quality. Sick building syndrome is a term used to describe a variety of particular symptoms caused by the interaction of numerous dangerous substances (pollutants) and indoor environment components, reflected in the comfort and health of building users. Sick building syndrome, which frequently causes a drop in workforce productivity, is becoming a substantial public health problem in many countries, mainly developed countries, and generates significant economic loss. However, it is observed that there is a lack of concrete data on the concept of healthy building and sick building syndrome, which has become a widespread problem. Indoor air quality, which can be defined as ventilation level or Carbon Dioxide (CO2) concentration, is influenced by "Volatile Organic Compound" (VOC) emissions from building surface materials and furniture, building occupants, and their activities. Total VOC concentration values are critical in developing effective strategies for creating a healthier and more comfortable living environment. The quantity and variety of physical, chemical, and biological contaminants in the interior environment present an urgent need for measures within the building production process to address potential health risks to building users. The literature research paper is about indoor air quality, which aims to describe healthy buildings and sick building syndrome, explain how to maintain indoor air quality through material used and architectural design, how chemical occurs and degrade air quality in the house, and how to measure, simulate and analyze through models.

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Martienssen, M., Riedel, R., Kühne, T.

Contribution of Professional Cleaning to Indoor Air and Sewage Pollution.

Sustainable Chemistry, Vol. **5** n°(4), (2024), 275-286 p.

In this study, several professional cleaning products were analyzed for their impact on local air and sewage contamination. The products were first analyzed for their content of potentially harmful ingredients, their biodegradability, and the potential for the mobilization of hazardous substances from the floorings that were cleaned. The contribution of the cleaning products to sewage pollution with environmentally hazardous substances was studied at full scale. All commercially available cleaning products studied were declared to be environmentally friendly (labeled with the EU Ecolabel). However, despite being labeled as “green” products, between 16 and 24 volatile harmful ingredients were identified. An optimized experimental product, produced completely from natural raw materials, also contained several harmful substances originating from the herbal raw materials themselves. During the field study, we identified a range of trace substances in the sewage. Eight of these substances (e.g., p-cymene, butanone, eucalyptol) significantly originated from the cleaning products. Several others may have originated from the cleaning products, but other sources were also possible. The flooring materials that were cleaned contained several harmful substances themselves. The release of some substances (e.g., toluene) into the sewage significantly increased during the cleaning process.

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Lovas, S., Pál, L., Kovács, N., Diószegi, J., Mckee, M., Szűcs, S.

Dataset on concentrations of volatile organic compounds in indoor environments of offices, educational and residential buildings in the European Union between 2010 and 2023.

Data in Brief, Vol. **57**, (2024)

Indoor air pollutants, such as volatile organic compounds (VOCs), include a range of hazardous substances that can accumulate in the indoor environments. As individuals spend 80–90 % of their daily time indoors, chronic exposure to VOCs has been recognised as an important public health concern. Therefore, measuring the concentration of indoor air pollutants is essential for improving indoor air quality and thereby reducing the associated burden of disease. Our objective was to generate a dataset on concentrations of VOCs measured in offices and in educational and residential buildings in the member states of the European Union between 2010 and 2023. Data were collected by means of systematic literature searches, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The search was carried out in the PubMed, Web of Science, and Scopus databases. In addition

to data on VOC levels, information on types of buildings, seasons when the measurements were performed, heating and ventilation systems, humidity and temperature at the sampling points, and methods used for sampling and analysis was collected. The dataset contains information on 18 VOCs and total volatile organic compounds (TVOC) from 101 original research papers. It consists of 19 worksheets, each with 46 columns, and the number of rows varies depending on the number of articles per VOC/TVOC, ranging from 11 to 576 rows. This dataset will be of use to public health professionals interested in using systematically collected data on VOC levels and corresponding reference concentrations to estimate the health risks associated with exposure to VOCs.

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Kakimoto, Y., Noro, K., Wang, Q., Miyake, Y., Amagai, T.

Determining the Exposure Routes and Risk Assessment of Isocyanates in Indoor Environments.

Archives of Environmental Contamination and Toxicology, Vol. **87** n°(4), (2024), 460-468 p.

Isocyanates are used as raw materials for polyurethane foams, paints, and building materials. The isocyanates can cause acute adverse health effects such as irritation of the respiratory tract, skin, and eyes, and induce asthma and sick house syndrome. However, investigations into the potential sources and risk assessments of indoor isocyanates are limited. Thus, this study aimed to determine the sources and exposure routes of isocyanates and to assess their risk in indoor environments. The results showed that household products, such as infant chairs, mattresses, and polyurethane foam spray, used in indoor environments are potential sources of atmospheric isocyanic acids (ICA). Toluene diisocyanate and methyl isocyanate pose relatively high risks to indoor environments. Total concentrations of isocyanates ranged from 38.2 to 1570 ng g−1 in infant chairs, mattresses, and spray polyurethane foams. The indoor products can be indoor sources of ICA because emission rates of ICA from household products were observed in all products (0.0536–1.37 ng g−1 d−1). Field observations showed that isocyanate concentrations in house-dust samples ranged from 0.194±0.126 (ethyl isocyanate) to 70.1±67.8 (ICA) ng g−1. Atmospheric isocyanate concentrations ranged from 0.0030±0.020 (propyl isocyanate) to 26.0±14.3 (ICA) ng m−3. An estimation of human exposure demonstrated that air inhalation was the major route of isocyanate exposure. The minimum margin of exposure values of methyl isocyanate and toluene diisocyanate were 523 and 655, respectively, for children, indicating that they may pose a relatively high risk.

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Lee, J. M., Lee, K. H., Moon, J. W., Lee, S. H., Hong, T.

Developing a Control Strategy for Minimum Airflow Setting Considering CO2 Level and Energy Consumption in a Variable Air Volume System.

International Journal of Thermophysics, Vol. **45** n°(12), (2024)

In an office building equipped with a Variable Air Volume (VAV) system, this paper introduces a novel method for controlling the minimum supply airflow fraction in each zone's VAV box, having a capability to consider indoor CO2 level and energy consumption. The EnergyPlus simulation using the medium office prototype model was employed, which evaluated the performance of the energy and CO2 concentration for five VAV box airflow control strategies. The paper focuses on CO2 concentration-based airflow control method and compares it with other four methods including conventional single-max, reduced minimum single-max, demand-controlled ventilation(DCV), and dualmax control methods according to guidelines and common practices. The newly proposed control strategy directly correlates the minimum airflow fraction to CO2 concentration. A general trend emerged when comparing CO2 concentrations—lower minimum airflow fractions were associated with higher concentrations. The proposed control method effectively maintained low CO2 concentrations and enabled a lower airflow fraction contributing to energy consumption reduction. It was confirmed that heating energy consumption in climate zone 4A, 5B, and 6A showed a maximum saving of approximately 30% compared to the conventional single-max and dual max control strategies. It was found that cooling energy consumption in climate zone 4A and 6A can achieve a maximum saving of approximately 10% compared to the conventional control strategies. The proposed

CO2 concentration-based control logic is promising as it not only improves the indoor air quality lowering the CO2 concentration in the occupied spaces, but also contributes to HVAC energy savings.

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Nguyen, M. T., Lee, J. S.

Development of a Chemical Sensor Device for Monitoring Hazardous Gases Generated in the Semiconductor Manufacturing Process.

Chemosensors, Vol. **12** n°(11), (2024)

The semiconductor industry plays a crucial role in various fields but also contributes to environmental degradation. Throughout the semiconductor chip manufacturing process, hazardous gases are released at each stage, despite stringent treatment procedures. These gases can be categorized into four groups: acidic and alkaline gases, volatile organic compounds, flammable and corrosive gases, and greenhouse gases. To meet stricter emission standards, further advancements in gas sensor technology are essential. This review examines recent research on monitoring these gases, highlighting the capabilities and limitations of existing sensor technologies. Additionally, the paper discusses current challenges in gas sensing research and proposes future directions for improving technologies.

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Chepaitis, P. S., Zhang, Q., Kalafut, D., Waddey, T., Wilson, M. J., Black, M.

The Effect of Moderate Temperature Rise on Emitted Chemicals from Modern Building Materials.

Buildings, Vol. **14** n°(11), (2024)

Chemical emissions from building materials may significantly impact indoor air quality and potentially human health, since individuals spend most of their time indoors. With rising global temperatures and more frequent heatwaves, building materials' resilience becomes more crucial for indoor air quality and structural integrity. However, the effects of temperature rise on building material emissions are not systematically studied. This study investigates the effect of a moderate temperature rise on the volatile organic compound (VOC) and aldehyde emissions of eighteen commonly used building materials, such as engineered hardwood, nylon carpet, terrazzo flooring, and acoustic tile, at two elevated yet realistic temperature points. The chemical emissions were collected using a micro-chamber setup and analyzed using thermal desorption/gas chromatography/mass spectrometry and high-performance liquid chromatography. The results showed that 78% of the materials tested demonstrated increased chemical emissions at higher temperatures. Wood-flooring materials showed statistically significant increases in formaldehyde at elevated temperatures, which could be associated with health risks. Eight of the tested materials, particularly those used in large surface area applications, showed significant increases in emissions at increased temperatures, and half of these were labeled as "low-VOC". These findings may inform the updating of building standards and third-party certification with respect to temperature variation when assessing building material emissions. This research aims to provide a comprehensive understanding of VOC and aldehyde emissions at emerging indoor environmental conditions due to extreme heat climate scenarios.

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Imran, M.

Energy performance analysis of pool air handling units and comparison of heat re-covery options.

Aalto University. Thèse 2024

Global energy consumption continues to rise due to advancements in technology, significantly contributing to climate change. Buildings play a crucial role in this trend, consuming about 40% of total energy, with swimming halls being among the highest energy consumers in this sector. There is a pressing need for more energyefficient systems that rely less on primary energy sources and more on recovered and

renewable energy resources. This thesis addresses the energy consumption of the air handling unit (AHU) in a swimming pool facility. A base model was first built for the Töölö swimming hall and validated using measured data from the BMS system, focusing on key factors such as supply and extract humidity and temperature. Three different AHU configurations were then simulated in IDA ICE: simple heat recovery, heat recovery with a heat pump, and heat recovery with an enthalpy wheel. The focus was to maintain consistent indoor parameters while comparing the energy consumption of these units with the validated simulation. The findings revealed that combining a heat pump with simple heat recovery significantly reduced the heating energy consumption of the pool AHU, lowering it from 18,710 kWh to 13,065 kWh, though this also led to an increase in electrical energy consumption. While this combination proved to be the most effective in enhancing overall energy efficiency, its high capital cost remains a significant limitation, warranting further research on its feasibility. Overall, this study emphasizes the potential for optimizing energy use in pool facilities while ensuring a comfortable indoor environment.

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Sánchez-Jiménez, J. L., De Adana, M. R.

Experimental study of ventilation performance of three ventilation strategies using aerosols and tracer gas.

Results in Engineering, Vol. **24**, (2024)

Effective ventilation plays a crucial role in reducing the risk of infection by airborne contaminants. This study was conducted in a hospital ward of specific dimensions (41.58 m3) equipped with two respiratory thermal manikins: a healthcare worker and an infected patient. Three ventilation strategies were employed in the ventilation system: supply and exhaust air through upper grilles, upper and lower grilles, and swirl diffusers with lower grilles. The air flow rate of the ventilation system was maintained constant at 200 m3/h. The airflow was distributed 50–50 % by a combination of a personalised ventilation system and personalised exhaust system. The effectiveness of a ventilation system and its combination with a personalised exhaust system was investigated using aerosol and tracer gas techniques. The efficacy of contaminant removal was evaluated in both the patient and healthcare inhaled volume. Determination of the clean air flow rate of the three ventilation system strategies at inhaled volume was carried out. Also, the exposure of healthcare worker to the contaminants exhaled by infected patient in the microenvironment formed by both was analysed. Experimental findings revealed that CO2 showed a higher ventilation efficiency compared to particles, independently of the ventilation strategy used. The highest clean air flow rate values were detected in the inhaled volume of patient infected. On the other hand, the highest particle removal efficiency was observed in swirl diffusers with lower grilles, which combined the ventilation system with the PES. This strategy also showed the lowest exposure values in the microenvironment.

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Gola, M., Laghezza, A., Yu, Y., Settimo, G., Capolongo, S.

How to promote health in indoor living and working spaces: quali-quantitative analysis to evaluate the indoor air quality through users' perception and low-cost sensors.

European Journal of Public Health, Vol. **34** n°(Supplement_3), (2024)

It is well-known that humans spend most of their time in indoor spaces: what it is sometimes underestimated; however, is how much the space in which someone is can affect their abilities, feelings and even their mental and physical health. A team developed a methodology to allow the collection of useful data and giving rise to management strategies for guaranteeing healthy spaces, in terms of Indoor Environmental Quality (IEQ). In particular, the methodology is based on a quali-quantitative analysis of Indoor Air Quality (IAQ) supported by a questionnaire on users' perception and well-being, based on a scoping review, and low-cost sensors for IAQ monitoring air contaminants (carbon dioxide, temperature, relative humidity, volatile organic compounds, etc.). In particular, for the quantitative analysis, the team adopted a method that considers the location of the sensors in different typology of settings with various solar exposures, ventilation systems, human occupancy, type of activity, etc. with the scope of testing the

trends in different seasons. As well as the qualitative data collect several information about the users' perceived comfort and the symptoms (headache, fatigue, etc.) during their stay. The data analysis highlights how the different users' perceptions affect the conditions of the environmental units, in particular in crowded rooms (4-6 people). Adequate lifestyles, such as door and window-openings, regular air-changes, etc. can highly affect the performances and the productivity, as well as the quality of the spaces. In that sense the use of low-cost sensors with light signals can be helpful as strategy for informing the user of the state of the air and any actions to be implemented. In conclusion, starting from the methodology, the team gives rise to a decalogue of strategies and good habits that permits -through the support of low-cost sensors - to inform the users on how to guarantee healthy living and working spaces.

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Justo Alonso, M., Breesch, H., Lassen, T. E., Carton, Q., Mathisen, H. M.

IAQ and ventilation measurements at the "ZEB Laboratory" office building in Norway.

Indoor Environments, Vol. **1** n°(4), (2024)

This study aims to assess indoor environmental quality (IEQ) within a Zero Emission Building (ZEB) office in Norway, focusing on occupant impact (CO2, temperature, humidity) and materials/substances influence (formaldehyde, particulate matter (PM2.5), total volatile organic compounds (TVOC)). It presents a detailed data collection spanning 14 months from March 30th, 2022, to June 1st, 2023. Occupancy varied significantly, affecting measured indoor air quality (IAQ) parameters, with the lowest temperatures recorded on the second floor and specific areas like the canteen experiencing temperature drops during low usage times. Relative humidity levels remained over 20 % in winter despite the building's low occupancy, a notable aspect given Norway's dry winters. PM2.5 levels stayed below World Health Organization (WHO) guidelines, indicating effective pollution management. The study also evaluates the impact of reducing the ventilation rates on IAQ, noting no significant IAQ compromise. An analysis correlating IAQ measurements with building occupants' satisfaction post-intervention revealed that temperature is the most significant factor affecting satisfaction levels, excluding acoustic satisfaction. Occupants generally reported satisfaction with the indoor environmental quality (IEQ), with specific dissatisfaction tied to thermal environment and IAQ, suggesting the importance of temperature control in occupant perception. This research not only provides valuable insights into IEQ management in Zero Energy and Zero Emission office buildings but also emphasizes the critical role of indoor temperature and the potential of wooden structures to stabilize humidity levels, contributing to occupant comfort and satisfaction.

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Askari, A.

Impact of Indoor Sources of Emission on Ambient Air Quality.

University of Toronto (Canada). Thèse 2024

This work presents a chemically speciated VCP emission inventory for Canada. I found the modifying impact of indoor physicochemical phenomena was negligible for more than 95% of VCP emissions before their transfer to the outdoor space. Furthermore, my analyses revealed that more than half the total VCPs' contribution to ambient OH reactivity and secondary organic aerosol formation in major urban areas in Canada between 2012 and 2017 originated from indoor spaces.

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Abbas, A. A., Elhassan, Z. A.

Improving Indoor Air Quality Through Coated Concrete: Sustainable Materials Application in Indoor Environment Under UV Irradiation.

2nd International Conference on Sustainability: Developments and Innovations. Riyadh, Saudi Arabia February 18 - 22, 2024

As concerns rise about the impact of air quality on human health, this research investigates air purification materials and techniques, particularly focusing on photocatalytic materials. The study assesses a system incorporating TiO2 and cement, aimed at addressing environmental pollution by integrating photocatalysts into construction materials. This photocatalytic method seeks to break down organic pollutants, while maintaining the visual appeal of concrete structures and removing air contaminants. The research involved experiments in A reactor designed for testing photocatalytic activity, employing concrete blocks coated with TiO2 under UV light. Toluene, a representative of volatile organic compounds (VOCs), was introduced at a level of 210 ppm. The effectiveness of toluene removal was measured using GC-FID and GC-MS multi-analyzer as it processed through the photocatalytic reactor. The findings reveal that TiO2 has a higher efficiency in adsorbing toluene and in photodegradation, achieving a reduction of 137 ppm in 5–7 h, proving its efficacy as a photocatalyst for enhancing indoor air quality.

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Shepherd, M., Bird, C.

Indoor Air Quality.

In: Principles of Occupational Health and Hygiene. CRC Press; 2024. 283-316 p.

This chapter provides an in-depth analysis of indoor air quality (IAQ) relevant to health and safety professionals. Beginning by defining IAQ, the chapter extends to explanation of the role of ventilation in shaping IAQ, building-related illnesses including sick building syndrome, and the correlation of broader indoor environmental quality (IEQ) and specifically IAQ with productivity. The chapter systematically addresses IAQ guidelines, examining major pollutants. A substantial portion is dedicated to the technical aspects of IAQ assessment, encompassing sampling protocols and measurement methods for diverse pollutants such as carbon dioxide, particulate matter, formaldehyde, volatile organic compounds, semi-volatile organic compounds, carbon monoxide, nitrogen dioxide, ozone, pesticides, bioaerosols, house dust mite allergen, radon, and odours. The chapter offers insights into the historical evolution of building ventilation and its importance in reducing the transmission of airborne infectious disease, the dynamics of indoor air pollutants, and strategies for effective IAQ control and improvement. Grounded in scientific rigour, this chapter serves as an essential reference for health and safety professionals seeking an in-depth understanding of IAQ parameters and their practical implications.

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Catrambone, M., Cappellina, M., Olivini, F., Possenti, E., Saccani, I., Sansonetti, A.

Indoor Air Quality in a Museum Storage Room: Conservation Issues Induced in Plastic Objects.

Atmosphere, Vol. **15** n°(12), (2024)

This study focuses on assessing the indoor air quality in a storage room (SR) belonging to Museo Nazionale Scienza e Tecnologia Leonardo da Vinci in Milan (MUST), covering pollutants originating from outdoor sources and emissions from historical plastic objects made from cellulose acetate (CA), cellulose nitrate (CN), and urea–formaldehyde (UF) stored in metal cabinets. The concentrations of SO2 (sulphur dioxide), NO2 (nitrogen dioxide), NOx (nitrogen oxides), HONO (nitrous acid), HNO3 (nitric acid), O3 (ozone), NH3 (ammonia), CH3COOH (acetic acid), and HCOOH (formic acid) were determined. The concentrations of SO2, O3, and NOx measured inside the metal cabinets were consistently lower compared to the other sampling sites. This result was expected due to their reactivity and the lack of internal sources. The SR and metal cabinets showed similar concentrations of NO and NO2, except for CA, where a high NO concentration was detected. The interaction between the CA surfaces and NO2 altered the distribution of NO and NO2, leading to a significant increase in NO. The presence of HNO3 potentially led to the formation of ammonium nitrate, as confirmed by ER-FTIR measurements. High levels of HONO and HNO3 in CN and NH3 in the UF indicate object deterioration, while elevated concentrations of CH3COOH in CA and HCOOH in the SR suggest specific degradation pathways for cellulose acetate and other organic materials, respectively. These results could direct conservators towards the most appropriate practical actions.

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Moldovan, F., Moldovan, L.

Indoor Air Quality in an Orthopedic Hospital from Romania.

Toxics, Vol. **12** n°(11), (2024)

Inside hospitals, there is a trend of increasing levels of air pollutants. However, only the indoor air quality in operating theaters is carefully monitored. Therefore, we set the goal of this study to evaluate the indoor air quality in areas of an orthopedics department and to compare the indoor air quality indices that characterize these areas. We used a monitoring system based on the Internet of Things with uRADMonitor model A3 sensors, with which we prospectively measured indoor air quality in the facilities of the orthopedic emergency hospital of Targu Mures in Romania, between 1 February 2023, and 31 January 2024. The primary target pollutants investigated in the emergency room, outpatient room and ward were carbon dioxide (CO2), nitrogen dioxide (NO2), volatile organic compounds (VOCs) and particles with a diameter smaller than 2.5 µm (PM2.5). We compared the effectiveness of the intervention for emergency rooms where air purifiers were working or not. The concentrations of CO2, VOCs and PM2.5 were significantly higher in the emergency room than in the outpatient room or ward. The indoor air quality was worst in winter, when the CO2, NO2 and VOC concentrations were at their highest. Air purifiers can help reduce the concentration of PM2.5 in emergency rooms. Medical staff and patients in orthopedic hospitals, especially in emergency rooms, are frequently exposed to polluted ambient air, which can affect their health. Orthopedic medical practice guidelines should address issues relating to the protection of personnel through the application of measures to improve indoor air quality.

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Gong, X., Li, Z., Zhao, L., Wang, T., Jin, R., Yan, X.*, et al.*

Indoor Air Quality Monitoring System with High Accuracy of Gas Classification and Concentration Prediction via Selective Mechanism Research.

ACS Sensors, Vol. **9** n°(11), (2024), 5828-5838 p.

The efficacy of sensors, particularly sensor arrays, lies in their selectivity. However, research on selectivity remains notably obscure and scarce. In this work, indoor pollutants (C7H8, HCHO, CH4, and NO2) were chosen as the target gas. Following the screening of six oxides from previous work, temperature-programmed desorption/reduction experiments were conducted to delve into the origins of selectivity. The results explicate the superiority of NiO in detecting toluene and unveil the distinctive NO2 sensing mechanism of WO3 sensors. Based on the sensor array comprising these oxides, it can clearly detect low concentrations of C7H8 (S = 1.6 to 50 ppb), HCHO (S = 1.4 to 50 ppb), and NO2 (S = 3.3 to 50 ppb), which satisfies the requisites of indoor air monitoring. Meanwhile, three machine learning models (Extreme Gradient Boosting, Support Vector Machine, and Back Propagation Neural Network) are employed for gas classification. The classification accuracies of these models are 95.45%, 100%, and 100%, while the R2 values of the concentration prediction are 99.65%, 94.9%, and 98.04%, respectively, indicating the rationality of material selection. Furthermore, it can still achieve relatively high accuracy in gas classification (94.12%) and concentration prediction (89.36%), even for gas mixtures of four gases. Finally, an indoor air quality monitoring system is developed, which enables real-time monitoring of indoor gas quality through the Internet of Things.

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Sørensen, S. B., Dalby, F. R., Olsen, S. K., Kristensen, K.

Influence of Germicidal UV (222 nm) Lamps on Ozone, Ultrafine Particles, and Volatile Organic Compounds in Indoor Office Spaces.

Environmental Science & Technology, Vol. **58** n°(45), (2024)

Germicidal ultraviolet lamps with a peak emission at 222 nm (GUV222) are gaining prominence as a safe and effective solution to reduce disease transmission in occupied indoor environments. While previous studies have reported O3 production from GUV222, less is known about their impact on other indoor constituents affecting indoor air quality, especially in real occupied environments. In this study, the effects of GUV222 on the levels of ozone (O3), ultrafine particles (UFPs), and volatile organic compounds (VOCs) were investigated across multiple offices with varying occupancies. O3 from the GUV222 operation was observed to increase linearly (~300 μg h–1 m–1) with a UV light path length from 0 to 3 m beyond which it stabilized. When applied in offices, the O3 production models based on continuous measurements revealed O3 production rates of 1040 ± 87 μg h–1. The resulting increases in steady-state concentrations of 5–21 μg m–3 were highly dependent on the number of office occupants. UFP production occurred during both unoccupied and occupied conditions but predominantly in newly renovated offices. Time-resolved measurements with a proton-transfer-reaction time-of-flight mass spectrometer (PTR-TOF-MS) revealed clear alterations in office VOC concentrations. Unsurprisingly, O3 oxidation chemistry was observed, including monoterpene deprivation and 4-oxopentanal (4-OPA) production. But additionally, significant alterations from unidentified mechanisms occurred, causing increased levels of various PTR-TOF-MS signals including C2H5O2+ and C4H9+ hypothesized to arise from photoinduced formation or off-gassing during the GUV222 lamp operation.

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Devaughn, A., Go, L. H. T., Cohen, R. A., Shao, Y.

Investigation of occupational exposure to respirable crystalline silica (RCS) among engineered stone fabricators in Chicago—A pilot study.

Journal of Occupational and Environmental Hygiene, (2024), 1-9 p.

Engineered stone countertops, popularly known as quartz or artificial stone countertops, have gained significant attraction due to their durability and aesthetic appeal. However, due to their high crystalline silica content, the fabrication of these countertops poses severe health risks to workers, as evidenced by numerous global cases of silicosis. The study aimed to assess occupational exposure to respirable crystalline silica (RCS) among fabricators in Chicago and characterize the elemental composition and physical properties of engineered stone dust. Eight professional fabricators from two local stone workshops were recruited for the study. The exposure levels to RCS were assessed using the NIOSH 7500 method. Bulk dust samples were collected on-site, and the elemental composition of the dust was analyzed using X-ray fluorescence (XRF) and reported in stoichiometric oxide units. A set of real-time air monitors was used to measure particle size distribution, particulate matter (PM) concentrations, and ambient conditions in the workplace. A questionnaire was administered, and worker activities were recorded during the visits. Workers were found to be overexposed to respirable quartz in their workplaces, with time-weighted averaged (TWA) concentrations ranging from 11 to 203 μg/m3, with a median concentration of 90 μg/m³. Seven samples (78%) exceeded the 50 μg/m3 TWA-8 hr occupational exposure limit for RCS. Engineered stone dust samples contain much higher silica content compared to natural stone dust (30%), with silica percentages ranging from 56% to 95%. Over 90% of the particles (90.3–98.7%) emitted from activities involving small hand tools were of size less than 2.5 μm. The use of respiratory protection was not observed during the visits. The study offers firsthand insights into the engineered stone fabrication industry. The findings reveal a combination of risk factors: elevated RCS concentrations, very high silica content in engineered stone, and a high prevalence of fine particles. These factors collectively pose significant health risks to workers that are unequaled in comparison to most other industries. The findings underscore the urgent need for regulatory measures to better protect workers' health in the engineered stone fabrication sector.

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Wang, H., Zhang, R., Kong, H., Wang, K., Sun, L., Yu, X.*, et al.*

Long-term emission characteristics of VOCs from building materials.

Journal of Hazardous Materials, Vol. **480**, (2024)

Long-term emission behaviors of volatile organic compounds (VOCs) from indoor buildings materials heavily depend on the value of three key parameters (initial concentration C0, diffusion coefficient Dm, partition coefficient K) that govern emissions over time. We made the first attempt to quantitatively explore the variation of parameters through a long-lasting aging test that simulates natural indoor exposure. Over a span of 431 days, we obtained a substantial dataset consisting of ten thousand data points. The parameters of six VOCs (formaldehyde, benzene, toluene, ethylbenzene, o-xylene, p-m-xylene) from three kinds of wood-based boards with different aging intervals were determined. Our findings demonstrate that C0 decreases exponentially with aging time, while Dm and K merely fluctuate with it. With the obtained correlations, ventilation time for renovated house is proposed to meet the WHO standard. These results lay the groundwork for predicting long-term indoor VOC concentrations, which is crucial for indoor air quality pre-evaluation.

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Chiu, C. W., Efstratiou, C., Nikolopoulou, M., Barker, M., Baldwin, A., Clarke, M.

A Machine Learning Framework for Optimising Indoor Thermal Comfort and Air Quality through Sensor Data Streams.

Proceedings of the 11th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation. Hangzhou, China. November 7 - 8, 2024

Optimising thermal comfort and air quality in indoor environments presents a complex, dynamic challenge that traditional static systems struggle to address effectively. We propose a novel real-time framework that tackles this multifaceted problem by leveraging stream clustering and time-series forecasting techniques. Our system continuously analyses sensor data to summarise comfort conditions and predict future indoor states. Simulations based on the stream clustering model indicate potential for significant improvements in indoor comfort, increasing comfort duration from 6% to 74%. Furthermore, the time-series forecasting model demonstrated strong performance, achieving mean absolute errors of 0.026 and 0.034 on test and demonstration datasets, respectively. This resource-efficient approach demonstrates promise for real-time indoor environment management, effectively balancing thermal comfort and air quality considerations.

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Funding, C. P.

The New Organizational Template: How to Design Work and Workplaces for Employee Health & Well-Being-December 8, 2014.

UC Berkeley. School of Public Health 2024

This title implies that we have a new organizational template for organizations, but unfortunately, we do not. The mission of the Interdisciplinary Center for Healthy Workplaces (“Center”) is to create a Center that is based on the best known science across multidisciplinary fields regarding factors that significantly impact employee health and well-being. It may take years, or it may only be a matter of getting a diverse set of experts together to talk and integrate their knowledge into a coherent and practical organizational strategy. The Center is striving to fulfill its mission by gathering all the known facts and research findings across a wide range of academic and research fields, identifying gaps in our existing knowledge, supporting interdisciplinary research to narrow those gaps, and integrating all known science into a coherent picture of how a healthy workplace looks, feels, operates, and stimulates healthy work behaviors, habits and personal lifestyle choices. Once this template is developed, the Center will disseminate the template and serve to enable researchers and practitioners dedicated to addressing the nation’s health crisis and facilitating effective organizational outcomes and employee behaviors.

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Lopes, M. B., Kanama, N., Poirier, B., Guyot, G., Ondarts, M., Gonze, E.*, et al.*

A Numerical and Experimental Study to Compare Different IAQ-Based Smart Ventilation Techniques.

Buildings, Vol. **14** n°(11), (2024)

Maintaining indoor environmental quality in residential buildings is essential for occupants' comfort, productivity, and health, with effective mechanical ventilation playing a key role in removing or diluting indoor pollutants. A two-week experimental campaign was conducted in an apartment in Lyon, France, known for its poor urban air quality, assessing temperature, relative humidity, CO2, and PM2.5 concentrations. A model verification study was performed to compare experimental measurements against numerical modeling in the living room and bedroom, leading to errors in the accuracy of the sensors. In addition, this study also investigates the impact of different ventilation strategies on indoor air quality. This research evaluates a baseline mechanical exhaust-only ventilation approach with constant air volume against two innovative smart ventilation approaches: mechanical exhaust-only ventilation with humidity control and mechanical exhaust-only ventilation with room-level CO2 and humidity control. A key contribution of this research is the novel coupling of multizone simulation models (DOMUS and CONTAM) with a CFD tool to refine pressure coefficients on the building façade, which enhances the accuracy of indoor air quality predictions. The smart ventilation strategies showed improvements, including a 20% reduction in CO2 concentration and a 5% reduction in the third-quartile PM2.5 concentration, highlighting their effectiveness in enhancing ventilation and pollutant dilution. This research provides valuable insights

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Almeida, E., Sandoval, D., Sánchez, A., Dávila, P. F.

On the Design of an AI Enabled Edge Workplace Environment Monitoring Station.

2024 IEEE Biennial Congress of Argentina (ARGENCON). 04 November 2024. San Nicolás de los Arroyos, Argentina

This paper reports on the design of an AI enabled edge workplace monitoring system. The system measures fluctuations in temperature, humidity, CO2 levels and human traffic. The project integrates a Raspberry Pi 4 unit with sensors for measuring variables. A camera and an Intel Neural Compute Stick 2 are incorporated for image processing for future investigation of how human traffic impacts environmental variables and likewise how these variables affect human behavior. Notably, the system is self-powered by a solar panel to enhance sustainability and portability.

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Prakash, A. K., Pereira, F. D. A., Bergés, M., Pritoni, M., Akinci, B.

Ontologies at Work: Analyzing Information Requirements for Model Predictive Control in Buildings.

Proceedings of the 11th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation

Model Predictive Control (MPC) has shown significant potential for improving energy efficiency, indoor air quality and occupant comfort of buildings. MPC-based control algorithms have also shown the ability to shift loads and optimize for multiple objectives, including but not limited to reducing the green-house gas emissions, energy costs and peak demand. However, one of the main implementation challenges of these control algorithms is the integration and configuration effort needed to deploy a supervisory MPC controller in a building. By assigning standardized references to information sources and control points in buildings, existing studies have shown that semantic ontologies and corresponding queries have the potential to ease the deployment of such controllers. Yet, the use of semantic information to ease the deployment processes of MPC controllers is still limited. In this paper, we review three MPC experiments and synthesize the information requirements of these optimization problems. We then turn to existing and upcoming semantic ontologies such as Brick, SAREF and ASHRAE Standard 223 to represent these requirements, evaluating their potential to support the implementation of an MPC controller. This investigation concludes with a discussion of existing opportunities and open questions that the community should explore to support more streamlined MPC implementations.

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Lans, J. L. A.

Operating Room Ventilation: A View From Different Perspectives.

Delft University of Technology. Thèse 2024

This thesis explores different ventilation systems used for operating rooms (OR). Entrainment test methods are used in most European standards to determine the protected zone whereas the air quality in the periphery is often excluded. Furthermore, these measurements are mostly carried out in an at-rest situation where intermittent sampling during operation should be required. Most ORs in the Netherlands have an air handling system with an ultra-clean ventilation system (UCV). ORs are energy-intensive departments, where air handling systems consume the most. Relatively simple adjustments can be made to the air handling system to reduce energy, such as expanding relative humidity limits and introducing operational clock times. Lowering outside air quantity has the biggest impact on energy reduction, lowering the OR classification the least. Reducing the air change rate in the OR from an ultra-clean to a generic OR will reduce the recovery degree and the local air change rate. Lowering the air change rate in operating rooms could harm comfort conditions and (ultra-clean) air quality. The capital and operational expenditures of air handling installations with an UCV-system are higher than those with a conventional system. The investment pays for itself when 2 to 4 surgical wound infections are prevented over the lifetime of the OR. The type of surgery should be a leading consideration in determining the typology of the air handling system and the type of air supply system. Absence of evidence that surgical site infections are prevented in ORs equipped with UCV-systems is not evidence that these are not prevented.

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Minassian, R., Mihăiţă, A.-S., Shirazi, A.

Optimizing indoor environmental prediction in smart buildings: A comparative analysis of deep learning models.

Energy and Buildings, Vol. **327**, (2025)

This paper presents a comprehensive investigation into the application of deep learning models for predicting indoor environmental quality in smart buildings. Using data collected from a network of microclimate sensors deployed across a university campus in Sydney, we evaluated the performance of Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), and hybrid CNN-LSTM models. Our study encompassed various aspects of model development, including data preparation, architecture design, hyperparameter optimization, and model interpretability. Contrary to common assumptions in time series forecasting, our results demonstrate that CNN models consistently outperformed LSTM and hybrid models in predicting indoor temperature. We found that multivariate input configurations enhanced prediction accuracy across all model types, highlighting the importance of capturing complex interactions between environmental parameters. Through SHapley Additive exPlanations (SHAP) analysis, we identified temperature, humidity, and Heating, Ventilation, and Air Conditioning (HVAC) status as the most influential features for predictions. Our experiments also revealed optimal configurations for historical input length and prediction horizon, providing practical guidelines for model implementation. This research contributes valuable insights for the development of more efficient and accurate smart building management systems, potentially leading to improved energy efficiency and occupant comfort in built environments.

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Adamović, S., Milošević, R., Banjanin, B., Dramićanin, M., Mićunović, M. I., Mihailović, A.

The particulate matter in the working environment of the digital printing machine detected by stationary and personal methods.

R Discovery, (2024)

Particulate matter (PM) emitted during the digital printing process is potentially dangerous in the sense that it penetrates deep into the operator's lungs. The mass concentration levels of PM1, PM2.5, and PM10

particles emitted in the working environment of digital machines were measured after applying two sampling methods, spatial and individual. A sensor sampler with an optical particle counter was used for the spatial method, while a personal sampler of particulate materials was applied for the individual process. The paper's primary goal is to assess the comparability of the concentration of PM particles obtained by different sampling methods.

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Abd Rahim, M. S., Yakub, F., Salim, S. a. Z. S., Dhamanti, I., Niranjana, G.

Performance Evaluation of Transformer and Informer-Based Models for Indoor Absolute Humidity Prediction using Outdoor Absolute Humidity.

10th International Exchange and Innovation Conference on Engineering & Sciences (IEICES 2024). October 17-18, 2024. Kyushu University, Fukuoka City, Japan

Predicting indoor absolute humidity is essential for effective building management, energy efficiency and occupant comfort. This research evaluates the performance of Transformer and Informer models in predicting indoor humidity using outdoor humidity data. The dataset consists of outdoor humidity measurements to forecast indoor conditions. We developed Transformer and Informer models to focus on attention mechanisms and sequence generation. Performance was evaluated using metrics such as MAPE, MSE, MAE, RMSE and R-squared. The Transformer model slightly outperforms the Informer model with a MAPE of 3.42% and an R-squared of 0.911, compared to the Informer's MAPE of 4.55% and R-squared of 0.867. This superior performance is due to the Transformer's enhanced attention mechanism and efficient sequence handling. This study provides advanced models for accurate indoor humidity prediction, with significant implications for building management and energy savings. Future research could explore real-time implementation and application to other environmental parameters.

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Singh, S., Vishwakarma, P., Gupta, T.

Review of Current and Future Indoor Air Purifying Technologies.

ACS ES&T Engineering, Vol. **4** n°(11), (2024), 2607-2630 p.

Air pollution poses the greatest risk of death for humans and has become a global cause of concern. The global population spends an average of 90% of their time indoors; therefore, the significance of indoor air quality (IAQ) on human health comes to the forefront. Most households, offices, restaurants, and other indoor places, whether in rural or urban areas, are facing the problem of indoor air pollution (IAP). This review begins by elucidating the health impact analysis of IAP and drawing parallels and distinctions between outdoor and indoor air pollution. This paper synthesizes a critical examination of existing commercial indoor air purifiers and sheds light on their limitations and drawbacks through a comprehensive review of the literature. The review then pivots toward the exploration of new technologies poised to revolutionize indoor air purification. From advanced filter manufacturing techniques to regenerating photocatalytic oxidation, this review outlines the possibilities to shape next-generation indoor air purifiers. Simultaneously, it discusses challenges holding back the integration of these technologies into commercial applications.

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Wang, Z., Zhao, X., Hong, F., Wang, H., Lei, H., Chou, Z.*, et al.*

Room-Temperature, Flexible Formaldehyde Gas Sensors Using Titanium-Incorporated 1T/2H MoS2.

ACS Applied Materials & Interfaces, Vol. **16** n°(47), (2024), 65185-65193 p.

The development of room-temperature (RT) formaldehyde sensors is significant for indoor air quality monitoring. In this contribution, titanium (Ti)-incorporated 1T/2H molybdenum disulfide (MoS2) phase heterostructures were prepared via a facile hydrothermal method. Compared with 1T/2H MoS2, the as-

prepared 1T/2H Mo1–xTixS2 nanosheets showed a boosted RT formaldehyde sensing performance, which was attributed to the enhanced gas adsorption and charge transfer processes induced by Ti incorporation and could be regulated by tuning the Mo/Ti ratio in Mo1–xTixS2. In addition, the Ti-incorporated phase heterostructures with an optimized 1T concentration showed further improved gas-sensing properties compared to the highly metallic or semiconducting nanosheets with the same chemical composition, which exhibited an obvious response of 0.035% to 1 ppm formaldehyde with an excellent limit of detection as low as 39 ppb, good repeatability, and short response and recovery times. Moreover, flexible gas sensors based on the optimized nanosheets showed well-maintained responses under moderately bent conditions. Our findings demonstrate that the creation of phase heterostructures with tunable compositions and phases may provide more opportunities to tailor their sensing properties.

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Budde, S., Chani, P. S., Agrawal, S.

Sensitizing Performance of Air purifiers for the High-Rise Commercial Buildings in Urban Core.

Frontiers in Sustainable Cities, Vol. **6**, (2024)

There are thousands of pollution monitoring stations which are recording the data 24x7, the present research question is using this data to solve bring out a relationship between natural ventilation and air conditioning. Recently, WHO reported that 14 out of the top 15 most polluted cities are in India. Every year there is a loss of 6.2% to the global economy due to air pollution. The recent urban PM2.5 smog spread over the whole of north India covering about 50% of the country's population. This event has been increasing the use of air purifiers and affecting the building energy performance.Most air purifiers (PM 10 and PM 2.5) are energy-intensive but are not always equipped with sensors. In commercial buildings, air purifiers are operated based on publicly relayed pollution information. The air pollutants that infiltrate into buildings are based on leaks, cracks, quality of building construction and pressure differences. Since indoor pollution levels are less than outdoor pollution levels, usage of air purifiers based on outdoor information leads to overperformance and hence energy wastage. Therefore, there is a need for optimization in sensitizing the performance of air purifiers at the building level. This study intends to assess the role of building airtightness and air purifier automation in lessening the air purifiers' electricity consumption in urban areas. Transient building simulation tools do not account for infiltrated pollution levels directly. Virtually evaluating the energy savings through air purifier automation and the building's airtightness would not be a straightforward assessment. The following paper uses EnergyPlus Energy Management System Class along with air pollution data monitored to model and simulate the Business-as-usual (BAU) and proposed Automation scenarios.

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Ganninger, R., Bernhold, T.

Session 4A: Indoor Environment Quality 1, IEQ.

Transdisciplinary Workplace Research. 4th-7 th September 2024. Edinburgh Napier University

Indoor environmental quality (IEQ) is broadly established as the composite of conditions within a building. Its influence on the satisfaction and productivity of knowledge workers is considered a prerequisite for a suitable working environment in the corporate office. However, the increasing spread of activity-based working (ABW) in the recent past raises the question of the extent to which the activity-based zones created in this context may also require a differentiated consideration of the IEQ to optimally support employees in different activities. As part of a post-occupancy evaluation (POE), 303 participants were interviewed zone-specifically at four locations of a German software company with an ABW concept incorporating five activity-oriented zones (Focus, Meeting, Phone, Group work and Refresh). Eight IEQ factors (i.e., temperature, air quality, acoustics) were assessed using the SERVQUAL methodology and analysed from two perspectives: First, a t-test revealed that users have significantly different expectations regarding specific IEQ factors for zones of different activities. Requirements for the IEQ in an ABW situation no longer appear to relate to the overall area 319 but require more focused consideration at the level of

specific activity-oriented zones in the planning process. Second, a multiple linear regression analysis was carried out to examine the extent to which the suitability of the zones for their respective activity depends on the fulfilment of IEQ factors during operation. The results show that, depending on the function of the zone, the IEQ factors influence perceived suitability and have differential effects. This work provides a basis for taking a new approach in the scientific discussion of IEQ and the alignment of research with the changing demands of the working environment. Furthermore, it provides concrete, practical implications that support the creation of suitable working environments from planning to operation.

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Hasan, Z., Haque, E., Khan, M. a. M., Khan, M. S.

Smart Ventilation Systems For Real-Time Pollution Control: A Review Of Ai-Driven Technologies In Air Quality Management.

Frontiers in Applied Engineering and Technology, Vol. **1** n°(01), (2024), 22-40 p.

This review paper examines the implementation and effectiveness of AI-powered smart ventilation systems for pollution control, focusing on industrial and urban environments. Utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, a systematic literature search was conducted across databases such as IEEE Xplore, ScienceDirect, and PubMed. Studies were screened and selected based on relevance to AI-driven ventilation systems, real-time air quality monitoring, and pollution management, resulting in a final set of 40 articles for in-depth analysis. The review synthesizes information on various technologies, including machine learning algorithms, Internet of Things (IoT) sensors, and pollutant scrubbers, that are integrated into smart ventilation systems to detect and respond to fluctuations in air quality autonomously. Key findings indicate that AI-powered systems can dynamically adjust airflow, filtration, and pollutant removal processes, leading to significant improvements in air quality in both industrial facilities and densely populated urban areas. This study highlights both the potential benefits and challenges associated with implementing AI-driven ventilation systems, including the need for high-quality data, real-time processing capabilities, and cost-efficiency. The review concludes with recommendations for future research directions, such as enhancing system interoperability and addressing ethical considerations in air quality monitoring and data privacy.,

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Link, M., Shore, A., Robertson, R., Hamadani, B., Poppendieck, D.

Spectral Characteristics and Indoor Air Quality Effects of Germicidal 254 nm and 222 nm Ultraviolet Light.

NIST Interagency/Internal Report (NISTIR), National Institute of Standards and Technology, Gaithersburg, MD 2024

Current Germicidal Ultraviolet (GUV) devices are designed to inactive pathogens in air at either 222 nm or 254 nm wavelengths. Previous research has demonstrated both wavelengths can produce oxidants in air (222 nm: ozone, 254 nm: hydroxyl radicals) and potentially directly photolyze some chemicals. This study sought to determine the impacts of GUV devices on indoor air chemistry in both laboratory chamber and field settings. To ensure the devices were operating using wavelengths and intensities of interest, spatial spectral irradiance measurements of one 222 nm (GUV222) and one 254 nm (GUV254) device were performed. Chamber testing to determine air quality impacts consisted of operating the above devices for four hours in a sealed chamber containing six challenge chemicals. Field testing consisted of operating the devices in an unoccupied restroom on the NIST campus. Ozone, formaldehyde, other volatile organic chemical (VOC) oxidation products and ultrafine particles were measured for each device in each scenario. In chamber experiments GUV254 generated formaldehyde and likely directly photolyzed an equivalent amount of acetone, contributing to a minimal net change in VOC oxidation products. In addition, GUV254 generated measurable ultrafine particles in the chamber experiments, albeit less than GUV222. For GUV254, formaldehyde, VOC oxidation products, ultrafine particles and ozone generation were not measurable in the restroom. In both the chamber and restroom installation GUV222 generated ozone, VOC

oxidation products and ultrafine particles. GUV222 generated quantifiable formaldehyde in chamber testing only. GUV222 was demonstrated to directly photolyze tetrachloroethylene in the chamber. Lastly, to better understand the irradiance spectrum in indoor spaces where GUV devices may be deployed, spatial and temporal changes to the 375 nm to 850 nm spectrum was examined at the NIST Net Zero Energy Residential Test Facility (NZERTF). A measurement location near a window was compared to measurement close to an internal ceiling. Indoor diurnal total irradiance and spectrums collected near the spring equinox and summer solstice were compared.

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Rolfsmeier, S., Rienhardt, W.

Trends in building and ductwork airtightness in Germany.

Ventilation Information Paper, Vol. **45** n°(13), (2024)

The objective of this paper is to give an overview of building airtightness and airtightness of ductwork in Germany. Before that, general information on the building stock and the construction market in Germany is provided. The German Energy Agency (dena) shares the following information on the building market in its 2023 report.

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Blond, N., Berger, C., Hauglustaine, D., Micolier, A., Mendez, M.

Un logiciel pour prédire la qualité de l'air dans les bâtiments.

Explorer l'environnement. Des solutions pour innover, (2024)

Le logiciel INCA-Indoor a été développé afin de simuler un millier de réactions chimiques, et les concentrations d'environ 900 espèces chimiques (gaz ou aérosols) au sein d'un bâtiment à partir de ses caractéristiques (volume, surface, type de matériaux, ventilation, température et humidité intérieur), de son occupation, des activités qui s'y déroulent, et de son environnement (pollution de l'air extérieur). Il détaille les phénomènes physico-chimiques et quantifie leur contribution à la pollution de l'air intérieur. Les interactions entre les polluants gazeux, les aérosols (particules liquides ou solides) et les surfaces des matériaux sont simulées. Le logiciel prend par exemple en compte l'utilisation d'un produit ménager qui émet un gaz (comme le d-limonène) qui peut réagir avec l'ozone de l'air ambiant (importé de l'extérieur) et conduire à la formation de très petites particules dans l'air. Plus les particules sont petites, plus elles pénètrent profondément dans le système respiratoire et sont dangereuses pour la santé. Dans l'air, les particules soit se regroupent pour former des particules plus grosses, soit grossissent car des gaz de l'air ambiant se condensent à leur surface. Avec INCA-Indoor, il est ainsi possible de comprendre toutes les voies de production et de destruction de la pollution de l'air depuis une émission de polluant, de quantifier l'exposition des occupants du bâtiment, et donc ses impacts sur la santé.

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Gaffet, E., Chevalier, D., Ferrari, L., Fouillet, B., Gaffet, É., Gaie-Levrel, F.*, et al.*

Valeurs repères d'aide à la gestion de la qualité de l'air intérieur pour le benzène.

HSCP 2024

Le HCSP recommande une Valeur Repère pour l'Air Intérieur (VRAI) pour le benzène de 6 ?g/m3 en prenant en compte un excès de risque de 10-5 pour les effets hématologiques cancérigènes sans seuil (VGAI long terme proposée par l'Anses en 2024). Le HCSP recommande également, en prenant en compte la faible fréquence de dépassement de cette concentration dans les différentes campagnes de mesure, de choisir la même valeur de 6 µg/m3 comme valeur seuil pour laquelle des investigations complémentaires doivent être menées et pour laquelle le préfet de département du lieu d'implantation de l'établissement est informé. Le HCSP se prononce également sur la méthode de mesure en recommandant, sur la base des travaux de l'Anses, un prélèvement actif d'une durée de 7 jours sur support

adsorbant, suivi d'une désorption chimique ou thermique et d'une analyse par GC/FID ou GC/MS pour la comparaison des mesures à la VRAI. Enfin, le HCSP recommande que les efforts pour limiter et réduire les expositions au benzène soient poursuivis et que la possibilité de proposer d'autres indicateurs de qualité d'air intérieur, comme le dioxyde d'azote ou les particules fines, PM2,5, soit étudiée.

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Waqas Alam, M., Sharma, A., Sharma, A., Kumar, S., Mohammad Junaid, P., Awad, M.

VOC Detection with Zinc Oxide Gas Sensors: A Review of Fabrication, Performance, and Emerging Applications.

Electroanalysis, (2024)

Abstract Energy-efficient, high-specificity gas sensors provide practical suitability for stability and response factors. The recognition of ignitable gases (methane (CH4), propane (C3H8), and hydrogen (H2) and harmful gases (carbon oxide (CO) and hydrogen sulfide (H2S)) in an enclosed and out-of-door space are essential to safeguard the human lives and infrastructural spaces. One of the crucial conductive-type metal oxide semiconductor (MOS) gas sensors yielding wide applications is zinc oxide (ZnO). This study highlights the various types of ZnO gas sensors, their fabrication techniques, and specific vital characterizations. The devices based on MOS are utilized to sense various target gases through redox reactions. The variation in oxide surface with target gas interactions is transduced to a change of sensor conductance. This review also provides insight into integrating ZnO gas sensors with technologies such as materials engineering, the Internet of things and big data. Moreover, this review addresses ZnO gas sensors? challenges and future directions.

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Zhang, L., Wu, W., Wang, J., Wang, Y., Zhang, Y., Wang, N.*, et al.*

Vocs pollution and respiratory exposure in commercial and residential underground parking garages.

Transportation Research Part D: Transport and Environment, Vol. **136**, (2024)

The indoor air quality in Underground Parking Garages (UPGs) has deteriorated significantly, primarily due to the high concentrations of particulate matter and volatile organic compounds (VOCs) emitted by idling or low-speed motor vehicles. However, the compositional characteristics and respiratory exposure to VOCs in UPGs have not been quantitatively analyzed. To establish a method for investigating the respiratory exposure to VOCs among different populations in UPGs, a three-dimensional dynamic diffusion model of indoor pollutants was developed based on monitoring data from 116 components in various UPGs in a large city in northern China. The results indicated that air pollution in underground spaces poses significant health risks to workers and children. Furthermore, a comprehensive approach is essential for improving ventilation capacity and air quality in underground transportation spaces.

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Nored, A., Fu, X., Qi, R., Batbaatar, N., Jia, C.

Volatile Organic Compound (VOC) Contamination in Hotel Rooms: A Pilot Study to Understand Sources and Health Risks.

International Journal of Environmental Research and Public Health, Vol. **21** n°(11), (2024)

The COVID-19 pandemic drove the use of cleaning products, causing organic solvent contamination in hospitality environments. This pilot study investigated the presence and concentrations of volatile organic compounds (VOCs) in selected hotels in four different US cities with varying star ratings at the end of the pandemic period. Targeting 139 VOCs, 57 were detected across eight groups: alcohols, halocarbons, aromatics, alkanes, terpenes, carbonyls, ethers, and esters, in the indoor air. Alcohols were the most prevalent, especially in lower-rated hotels, suggesting higher use of cleaning supplies. Elevated levels of

aromatics were detected in hotels rated under three stars, with a notable disparity compared to higher-rated hotels. Additionally, alkanes and terpenes such as n-tetradecane and d-limonene were consistently detected. Health risk assessment showed concentrations of all VOCs remained below their health criteria for customers. The cumulative cancer risk was 2.25 × 10−6 for hotel workers from chronic occupational exposure to eight carcinogenic VOCs, representing 1/3 of the lifetime risk from these chemicals in the ambient air. Cancer risks from individual VOCs ranged from 0.001 × 10−6 to 1.07 × 10−6, with chloroform accounting for nearly half of the cumulative risk. The findings underscore the need for careful selection and use of furnishings and cleaning supplies and for effective indoor air pollution control and management in hotel indoor environments.

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