UKIEG Annual Conference and AGM 2024 Monitoring and big data for driving the research and policy agenda for IEQ and health

University of Strathclyde Glasgow

WITH SUPPORT FROM Google.org

Impact of Outdoor Air on Indoor Air Quality in Urban Office Environments:

A Case Study from the Royal College Building in Glasgow

Dr Alejandro Moreno-Rangel[1*], Dr Sara Mohamed[1], Prof Tim Sharpe[1], HEICCAM Network[2]

[1]Department of Architecture, University of Strathclyde, Glasgow, G3 6UA, United Kingdom, *corresponding author: alejandro.moreno-rangel@strath.ac.uk

[2]School of Geosciences, University of Edinburgh, Edinburgh, EH8 9XP, UK

Abstract

This research examines both indoor and outdoor air quality (IAQ) across seven offices within the Royal College building in Glasgow, explicitly analysing levels of carbon dioxide (CO2), volatile organic compounds (VOCs), and particulate matter (PM10 and PM2.5). Through continuous monitoring, this study evaluates fluctuations in IAQ parameters and the influence of external pollution sources on indoor air quality. Preliminary findings indicate a notable observation: offices with windows facing the main road show increased particulate matter concentrations when windows are open, compared to baseline levels. This highlights the significant impact of external traffic emissions on indoor air quality, especially when windows are open. The study underscores the importance of heightened awareness regarding ventilation practices and the development of local government strategies to reduce outdoor pollution. These findings are crucial for shaping workplace health policies and suggest modifications in building operational strategies to enhance air quality.

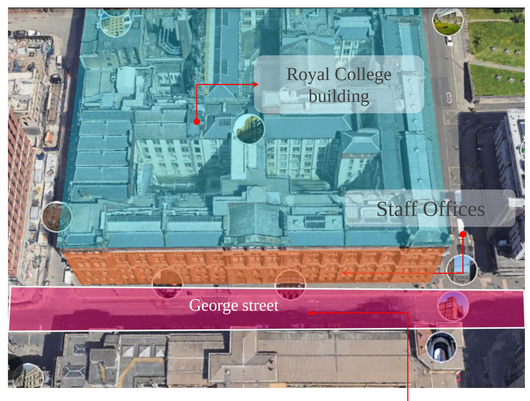
This investigation enriches our understanding of the complex interactions between external air pollution sources and indoor environments, providing important insights for future urban planning in Glasgow and related public health initiatives.

Methods

- Deployed sensors in staff offices to continuously monitor CO2, VOCs, PM2.5, PM10, PM1.0, temperature, and humidity based on a site survey since November 2023.
- Integrated sensor locations in the offices, as shown in the 2D and 3D plans in the figures.
- Established/plotted the indoor air quality baselines.
- Continuous monitoring of air quality parameters for temporal variations.
- Analysed data to identify pollutant sources and assess mitigation strategies.

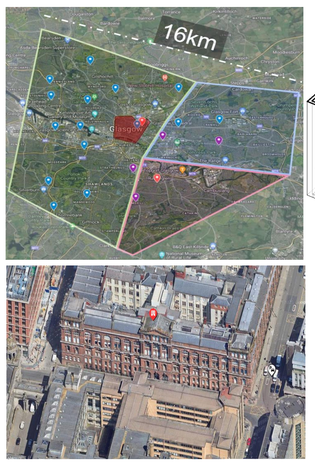
Objective:

- Promote a healthier indoor environment in staff offices through continuous monitoring, data analysis, and optimization of air quality parameters for occupant well-being.

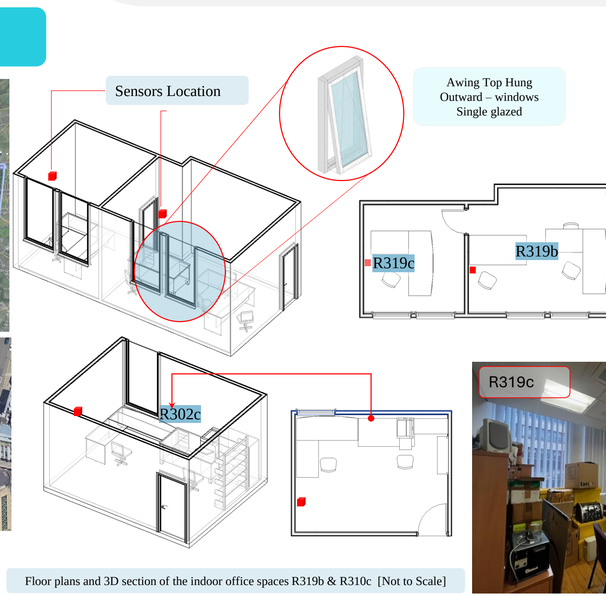


Introduction

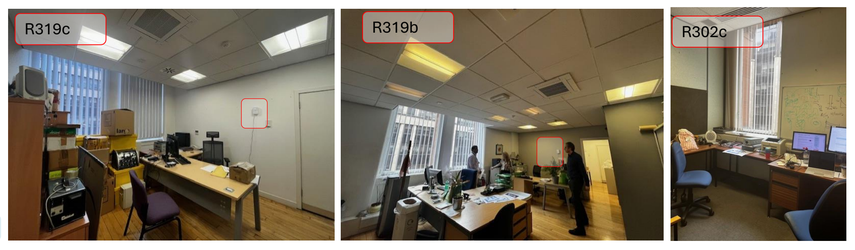
- The outdoor BEACO2N installation in Glasgow monitors various air quality parameters like CO, CO2, O3, particulate matter, NO, NO2, temperature, pressure, and humidity. Additional data are collected, and sensors are operational.
- Indoor air quality (IAQ) monitoring has begun at the Royal College building, with plans to extend to schools. This poster shows efforts to collect IAQ data from staff offices at the Royal College. The next step is to monitor educational institutions and workplaces, comparing indoor data with outdoor BEACO2N readings.
- This comprehensive monitoring approach aims to provide insights into indoor and outdoor air quality, enabling informed decisions and strategies for improving environmental conditions in both settings.



The figures show the BEACO2N outdoor sensor network in Glasgow on Google Maps.

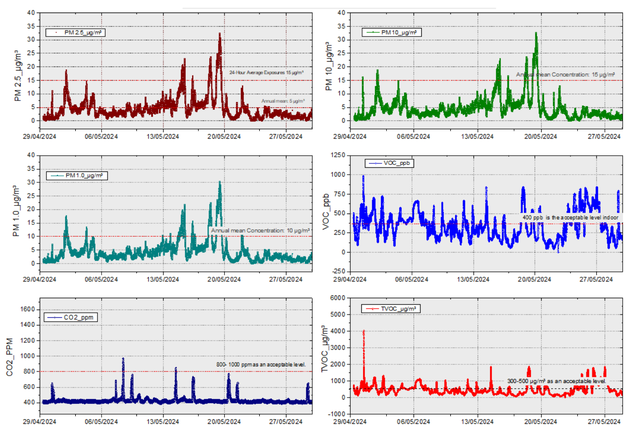


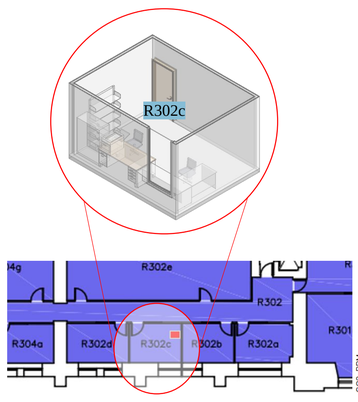
Floor plans and 3D section of the indoor office spaces R319b & R310c [Not to Scale]



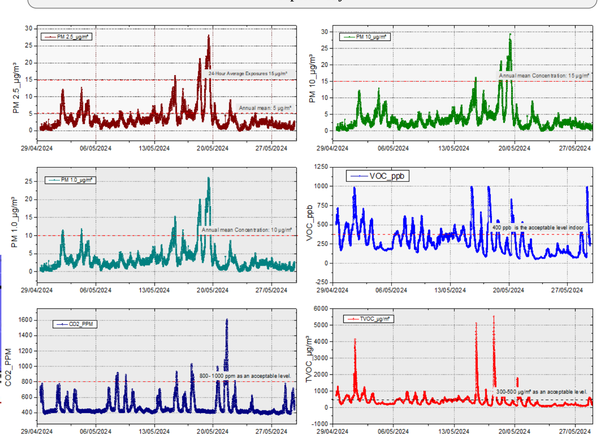
Results and Discussion

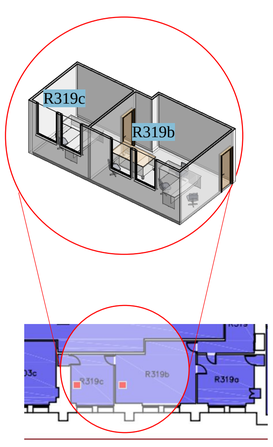
IAQ Levels in Indoor Office Environment _R302c_Office in Royal College Building April/May



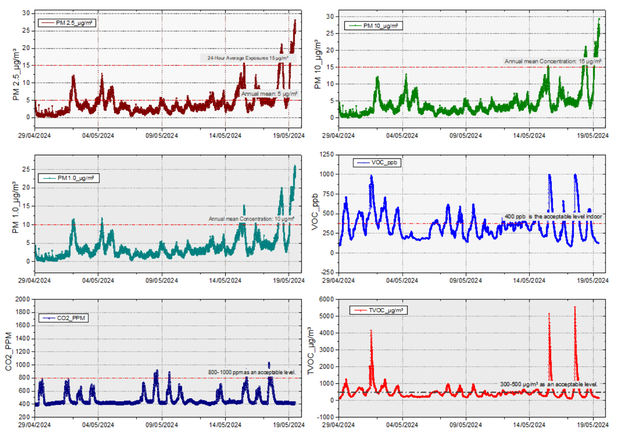


IAQ Levels in Indoor Office Environment _R319b_Office in Royal College Building April/May



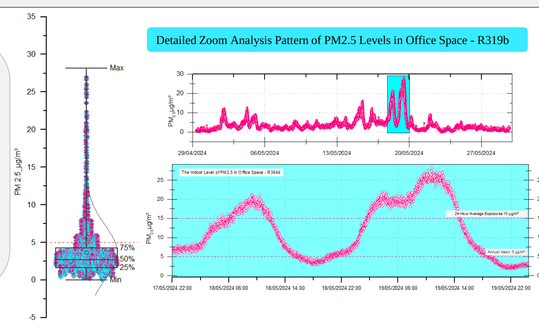


IAQ Levels in Indoor Office Environment _R319c_Office in Royal College Building April/May



IAQ Levels in Selected Offices inside Royal College Building (April 2024):PM2.5: Several peaks exceed the 24-hour limit of 15 µg/m³ and the annual mean limit of 5 µg/m³, indicating poor air quality.PM10: Frequent spikes surpass the 24-hour limit of 50 µg/m³ and the annual mean limit of 15 µg/m³, suggesting elevated particulate levels.PM1.0: Peaks often exceed the recommended annual mean concentration of 10 µg/m³, indicating significant ultrafine particle levels': Frequent fluctuations with values exceeding the 400 ppb limit, with peaks around 1000 ppb, raising air quality concerns.CO2: Generally within the 800-1000 ppm range, but occasional peaks indicate inadequate ventilation's: Mostly exceeds the acceptable level of 300-500 µg/m³, with occasional spikes up to 800 µg/m³ or even 5000 µg/m³, suggesting pollution sources from traffic as the office faced the main road.

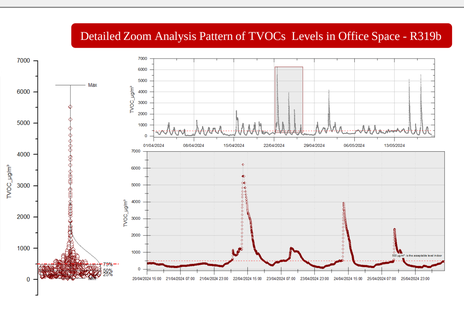
- Multiple PM2.5 peaks exceed daily and annual limits
- Cyclical pattern with peaks during office hours
- Peak PM2.5 levels around 35 µg/m³, over double the daily limit
- Nearness/facing the space to busy main road likely causes elevated indoor PM2.5 levels from traffic emissions insightful the office space



Detailed Zoom Analysis Pattern of PM2.5 Levels in Office Space - R319b

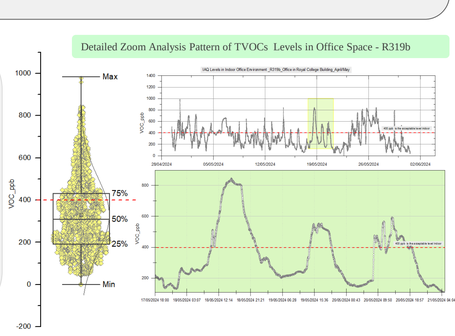
- TVOC levels fluctuate greatly, often >4000 µg/m³
- Peak near 6000 µg/m³
- Daily pattern: lowest early morning, increases through day, peaks late afternoon/evening >5000 µg/m³
- Acceptable level (500 µg/m³) exceeded most of each day
- Staff Office space near road: persistently high levels, health concerns
- Traffic likely major source
- Very high exposure above acceptable levels

Detailed Zoom Analysis Pattern of TVOCs Levels in Office Space - R319b

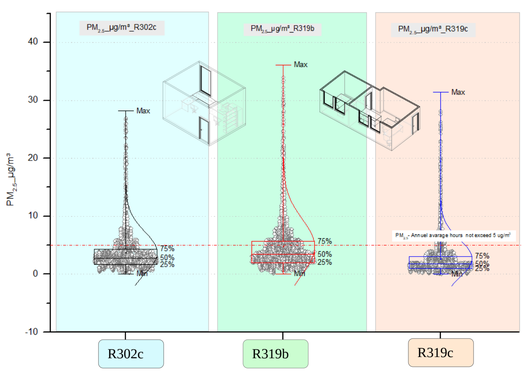


- VOC results show regular spikes above 1000 ppb, exceeding the acceptable level of ~400 ppb
- May 19-20: VOC levels lowest overnight and early morning, peaking at 600-800 ppb in afternoon and evening
- Office Staff , which windows facing busy road: elevated VOC levels are concerning.
- Traffic emissions likely contribute to high concentrations, especially during peak commute times
- Frequent and lengthy exceedances of acceptable levels may cause adverse health effects: Respirator, irritation, Headaches, Dizziness

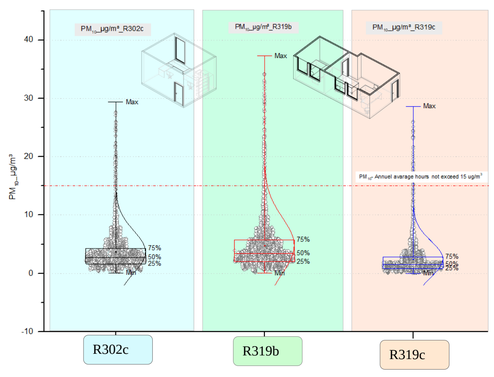
Detailed Zoom Analysis Pattern of TVOCs Levels in Office Space - R319b



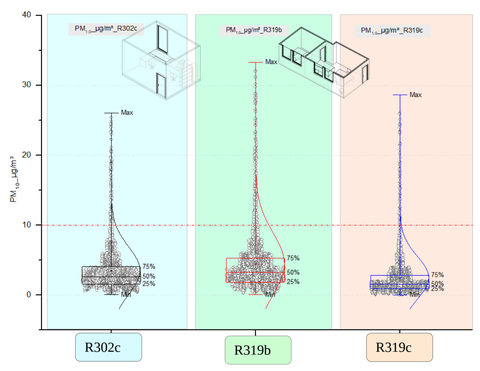
$PM_{2.5}$ Concentrations in Office Spaces - R302c, R319b, and R319c



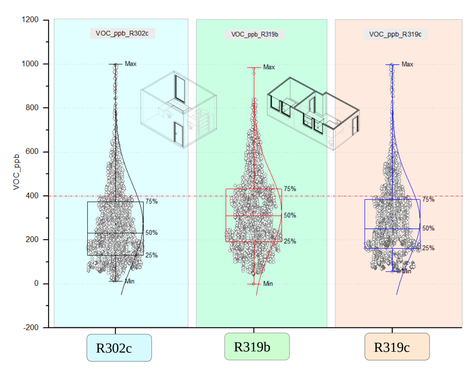
PM_{10} Concentrations in Office Spaces - R302c, R319b, and R319c



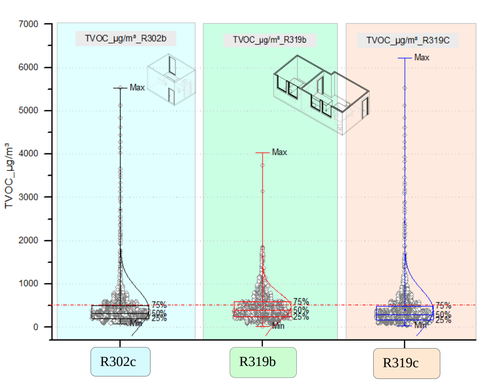
$PM_{1.0}$ Concentrations in Office Spaces - R302c, R319b, and R319c



VOC Concentrations in Office Spaces: R302c, R319b, and R319c



TVOC Concentrations in Office Spaces: R302c, R319b, and R319c



Conclusion

- IAQ in staff offices near busy road is suboptimal, VOC and TVOC levels frequently exceed recommended thresholds
- Daily patterns show peak concentrations in afternoons and evenings, Likely due to traffic-related emissions
- Persistent exposure to high pollutant levels raises health concerns for staff/users
- Urgent action needed to enhance IAQ and protect employee well-being.Particularly important in offices exposed to high vehicular emissions.
- Recommended strategies: Optimize ventilation rates for adequate fresh air exchange. Improve window sealing to minimize outdoor contaminant infiltration
- Further research warranted to assess intervention effectiveness and explore additional strategies.

References

Ferdyn-Grygierek, J. 2016. Monitoring of indoor air parameters in large museum exhibition halls with and without air-conditioning systems. Building and Environment, 107, 113-126.(Organization 1982, Organization 2010, Sundell,

Levin et al. 2011, Hesaraki and Holmberg 2015, Ferdyn-Grygierek 2016, Kalimeri, Saraga et al. 2016, Tsai 2019, Kotzias 2021)

Hesaraki, A. & Holmberg, S. 2015. Demand-controlled ventilation in new residential buildings: Consequences on indoor air quality and energy savings. Indoor and Built Environment, 24, 162-173.

Kalimeri, K.K., Saraga, D.E., Lazaridis, V.D., Legkas, N.A., Missia, D.A., Tolis, E.I. & Bartzis, J.G. 2016. Indoor air quality investigation of the school environment and estimated health risks: Two-season measurements in primary schools in kozani, greece. Atmospheric Pollution Research, 7, 1128-1142.

Kotzias, D. 2021. Built environment and indoor air quality: The case of volatile organic compounds. AIMS Environmental Science, 8, 135-147.

Organization, W.H. 1982. Indoor air pollutants: Exposure and health effects.
Organization, W.H. 2010. Who guidelines for indoor air quality: Selected pollutants, World Health Organization. Regional Office for Europe.

Sundell, J., Levin, H., Nazaroff, W.W., Cain, W.S., Fisk, W.J., Grimsrud, D.T., Gyntelberg, F., Li, Y., Persily, A. & Pickering, A. 2011. Ventilation rates and health: Multidisciplinary review of the scientific literature. Indoor air, 21, 191-204.

Tsai, W.-T. 2019. An overview of health hazards of volatile organic compounds regulated as indoor air pollutants. Reviews on environmental health, 34, 81-89.
(Organization, 1982)