Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33089

Spatio-Temporal Dynamics of Aerosols and Reactive Gases in an Urban Hospital Micro-Environment: Implications for Air Quality

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Air pollutants, including atmospheric aerosols and reactive nitrogen species, play a central role in urban air quality and climate impacts. Understanding their spatio-temporal variability and transport pathways is essential for effective mitigation. While outdoor urban air pollution is well studied, few datasets resolve the coupling between ambient atmospheric processes and indoor environments at high temporal resolution.

This study presents a three-year spatio-temporal assessment of aerosols ($PM_{2.5}$, PM_{10}) and reactive gases (NO_2) across two large urban hospital sites in northeast England. A dense network of over 40 sensors was deployed to continuously monitor indoor and outdoor pollutant concentrations, enabling detailed analysis of pollutant gradients, temporal variability, and dominant atmospheric drivers.

Results show that short-term indoor particulate variability is influenced by internal activity; however, ambient atmospheric transport exerts the primary control on indoor PM concentrations. Elevated indoor aerosol and NO_2 levels were associated with specific sectoral wind conditions, indicating strong coupling between outdoor atmospheric dynamics and building ventilation systems. HVAC operation was observed to modulate pollutant ingress, with periods of enhanced indoor concentrations linked to advective transport during polluted wind sectors.

Targeted operational adjustments informed by atmospheric conditions, including temporary HVAC shutdown under adverse wind regimes, indicate that indoor particulate exposure could be reduced by up to 3%. This demonstrates the sensitivity of indoor environments to external atmospheric pollution drivers and highlights the potential for operational optimisation.

These findings highlight the importance of integrating high-resolution atmospheric observations with built-environment systems to better characterise the behaviour of aerosols and reactive gases in urban micro-environments. The study provides new insights into indoor–outdoor coupling of air pollutants and demonstrates how applied monitoring can inform mitigation strategies relevant to air quality management and climate-active pollutant reduction.