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From Monitoring to Mitigation: High-Resolution Aerosol and NO_2 Characterisation Supporting Net-Zero Hospital Air-Quality Frameworks

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High-resolution characterisation of atmospheric aerosols (PM_{10}, $PM_{2.5}$) and reactive gases such as NO_2 is essential for understanding urban air-quality dynamics and identifying mitigation pathways that support net-zero objectives. These pollutants are key components of urban atmospheric systems, influenced by transport, energy use, and meteorological forcing, and contribute to environmental degradation and climate forcing.

Healthcare facilities represent complex urban micro-environments that can act as both receptors and sources of atmospheric pollutants. In the UK, healthcare activity accounts for approximately 3–5% of national greenhouse gas emissions, with road transport associated with the National Health Service contributing around 3.5% of total road travel, underscoring the need for targeted, evidence-based interventions within hospital estates.

This study presents a multi-year spatio-temporal assessment of air quality across two major hospital sites in northeast England. A network of over 40 sensors was deployed to continuously measure indoor and outdoor NO_2, $PM_{2.5}$, PM_{10}, and CO_2 at high temporal resolution over a three-year period, enabling identification of pollutant gradients, hotspots, and dominant drivers controlling indoor and outdoor concentrations.

Results indicate that while short-term indoor PM variability is influenced by human activity, ambient pollutant transport is the dominant control on indoor particulate concentrations. HVAC operation modulates indoor aerosol levels, with elevated concentrations associated with specific sectoral wind conditions, demonstrating coupling between building systems and atmospheric transport processes. Targeted operational interventions, including temporary HVAC shutdown during adverse wind sectors, reduced indoor particulate exposure by up to 3%.

These findings informed the implementation of the Clean Air Hospital Framework (CAHF), translating atmospheric monitoring data into operational and strategic actions that address air pollution and greenhouse gas emissions simultaneously. This case study demonstrates how academic and institutional collaboration, supported by dense environmental monitoring, can deliver scalable and geochemically informed solutions for air quality management within the healthcare sector, contributing to broader net-zero transition goals