



Open-Tool Frameworks for Cross-Platform Indoor Monitoring and Optimized Air Cleaning Strategie

Federico Dallo¹, Lorenzo Tenti¹, Alessandro Palo², Thomas Parkinson³, and Carlos Duarte⁴

¹National Research Council of Italy, Institute of Polar Sciences, Bologna, Italy (federico.dallo@cnr.it)

²Ca' Foscari University of Venice, Interdepartmental Centre of Services for Experimental Disciplines, Venice, Italy

³The University of Sydney School of Architecture, Design and Planning, Sydney, Australia

⁴University of California at Berkeley, Center for the Built Environment, Berkeley, USA

Indoor environments account for most human exposure to air pollution, yet indoor air quality (IAQ) monitoring and control remain fragmented across devices, platforms, and proprietary building automation systems. Commercial IAQ monitors and smart thermostats are widely available, but they typically operate in closed ecosystems with limited interoperability. In parallel, open-source communities have demonstrated the potential of low-cost sensing networks, yet these solutions rarely connect to building-level control systems capable of simultaneously reducing pollutant exposure and energy use. To address this gap, we present an open, interoperable framework that integrates open-source and commercial technologies for IAQ monitoring, data management, and automated building control[1]. The framework, developed within the EU-funded healthRiskADAPT project, is built on an open, production-ready IoT infrastructure for indoor environments. At the edge, low-cost sensor nodes collect and transmit environmental data. A web-based interface allows users to register locations, nodes, and sensors, and provides near-real-time visualization, historical analytics, and an interactive map of the sensor network. Beyond monitoring, the framework enables direct integration with commercial control devices such as smart thermostats, smart plugs, and filtration systems. This interoperability supports data-driven control strategies, including increasing ventilation during indoor pollution events, activating filtration during periods of poor outdoor air quality, and dynamically adjusting HVAC operation to balance comfort, energy use, and exposure reduction. By combining continuous mass-balance modeling[2] with real-time sensor data, the system will deliver actionable indoor-outdoor (I/O) ratios and exposure indicators. These outputs could drive automated responses but also support informed user behavior, such as choosing higher-efficiency filters during high-pollution episodes, using kitchen exhaust during cooking, or understanding the trade-offs between energy costs and health risks. In this way, the platform functions not only as a control system but also as an educational and decision-support tool for occupants and building managers. This presentation demonstrates how open-source hardware, open APIs, and modular integration pathways can create a flexible, transparent, and scalable ecosystem for IAQ management. The framework supports diverse use cases, homes, schools, workplaces, and research settings, while offering a roadmap toward energy-efficient, healthier indoor environments driven by interoperable technologies rather than isolated products.

[1] <https://particularmatter.org>

[2] Dallo, Federico, Thomas Parkinson, Carlos Duarte, Stefano Schiavon, Chai Yoon Um, Mark P. Modera, Paul Raftery, Carlo Barbante, and Brett C. Singer. "Using smart thermostats to reduce indoor exposure to wildfire fine particulate matter (PM_{2.5})."
Indoor Environments 2, no. 2 (2025): 100088.