Data processing possibilities for large-scale IAQ prediction

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ABSTRACT

Indoor air quality (IAQ) in residential buildings is a key determinant of occupants' health, yet its assessment in existing dwellings remains limited, particularly at large scale. In Spain, natural ventilation based on window opening, thermal draft and air infiltration through the building envelope is still predominant. Over recent decades, European Union energy policies—particularly those linked to energy efficiency and climate mitigation—have strongly promoted building renovation and envelope airtightness. While effective in reducing energy demand, these interventions have frequently led to unintended negative impacts on IAQ, especially in dwellings relying on natural ventilation where reduced infiltration is not compensated by mechanical systems.

Current EU policy frameworks, including the Energy Performance of Buildings Directive and the Renovation Wave, are progressively evolving towards a more holistic approach that integrates energy performance, health and indoor environmental quality. However, the incorporation of IAQ into building refurbishment and incentive schemes requires a robust understanding of the actual conditions of the existing housing stock, as well as scalable and cost-effective methods to assess IAQ at large scale and identify priority areas for improvement.

This communication investigates data processing strategies that enable large-scale IAQ prediction in naturally ventilated dwellings without relying on ventilation flow rate measurements. The research is based on the hypothesis that indoor CO_2 concentration, as an indicator of IAQ, can be predicted using a reduced set of easily obtainable parameters. The main objective was to develop a predictive model for IAQ in existing dwellings, supported by two subsidiary aims: to characterise IAQ conditions in naturally ventilated housing and to provide technical evidence to support regulatory adaptations facilitating the use of natural ventilation.

An experimental campaign was conducted in 12 single-storey dwellings located in multifamily residential buildings in Madrid, covering 42 rooms and 75 measurement cases. A generalised linear model was developed to estimate average indoor CO_2 concentration using five input variables: season, room use, dwelling floor area, regular occupancy and number of façades with openings. The model demonstrates high explanatory capacity and robust predictive performance, enabling IAQ estimation without continuous monitoring.

The results show that approximately half of the monitored dwellings do not comply with current IAQ requirements, with excessive CO_2 levels in bedrooms identified as the main cause of non-compliance, particularly during winter. Occupants' ventilation behaviour was found to be a critical influencing factor. By enabling IAQ assessment at scale using readily available data, the proposed approach supports evidence-based policymaking and provides a practical foundation for integrating IAQ considerations into future EU energy renovation strategies and building regulations.

KEYWORDS

Indoor air quality regulation, Building code, natural ventilation, CO_2-based performance criteria, Predictive modelling