Filling the Indoor Air Quality Data Gap: Research Challenges and Opportunities

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SUMMARY

The rapid growth in the use of low-cost sensors for indoor air quality (IAQ) measurement campaigns, following the COVID-19 pandemic, has significantly improved public awareness of ventilation and IAQ in buildings. Yet, we still know very little about the level of pollutants in our indoor environments. Unlike outdoor air, IAQ is not routinely actively monitored and there are currently no widely accepted, standardised methodologies, procedures or regulations for doing so.

No systematic long-term monitoring of IAQ in the UK or Ireland exists, despite recent calls to establish a large-scale programme akin to those already present in France and the US. The standard practice of short-term, sporadic measurements is not sufficient to determine total exposure or to quantify current levels of ventilation in the existing building stock. This information is vital to determine the effectiveness of current policy and to provide the basis for future decision making, such as pandemic preparation or building standards.

Such a systematic, long-term UK monitoring programme or *observatory* would offer an unprecedented opportunity to quantify current ventilation and indoor pollution exposure, while providing data to establish the impact of changes to behaviour and policy over time, such as improved energy standards, higher internal temperatures and increasing levels of airtightness. However, before this can be achieved, key challenges must be addressed. A standardised, validated method of measuring and recording IAQ and building data is now essential to support the collation of large-scale datasets. An integrated approach to remote low-cost sensor-based monitoring would help maximise any future monitoring campaigns and ensure data is captured in the most effective way. Moreover, there is a real opportunity to capitalise on the significant increase in IAQ monitoring through the growth of consumer-oriented air pollution sensors and sensor-based ventilation control systems, to help fill the IAQ data gap.

This paper presents a review of existing monitoring standards/guidance and available datasets to propose a roadmap to standardise the collection, storage and analysis of IAQ data for the purpose of evidencing the impact on health. This information will provide a useful resource for researchers and practitioners interested in measuring building performance and IAQ. Future research directions and opportunities are also discussed, with strategies presented on how to fill the IAQ data gap.

KEYWORDS

Monitoring protocols, data connectivity, standardisation, roadmap

1 BACKGROUND

Capturing high-quality indoor air quality (IAQ) and ventilation data in housing at a national level is critical to inform future building standards and ultimately improve public health. Measurement is key to management; without comprehensive, regular monitoring of indoor pollutant exposure and ventilation in a representative sample of the housing stock it is impossible to quantify the impact of strategies to reduce exposure and associated health effects.

Moreover, measurement without sufficient contextual information can result in significant gaps in overall knowledge; in other words, *data without context is just noise*. Whilst the overall number of monitoring studies have been gradually increasing, the lack of internationally accepted measurement protocols and lack of contextual information mean comparisons between studies are difficult. Given the variability and complexity of the indoor environment, monitoring studies are often small in scale and can vary significantly in nature.

At present, there is no nationally representative data on ventilation levels in UK or Irish homes. A recent survey of ventilation provision in Great Britain found 71% of homes did not have minimum ventilation provision in adherence with long-standing building regulations (Van Rooyen & Sharpe, 2024). Airflow rate measurements taken in 52 homes as part of the UK Building Performance Evaluation Programme found 44% of systems did not meet the designed airflow rate (Sharpe et al. 2016). Similarly, a study by MHCLG (2019) found only 3 out of 80 monitored homes met minimum ventilation regulations.

The House Condition Survey is conducted annually in England and Scotland, providing valuable information on the quality and energy performance of a representative sample of housing stock, however, data for the rest of the UK is significantly limited. In Ireland, the last Irish National Survey of Housing Quality was conducted in 2002.

Likewise, there is no national monitoring programme for the UK or Ireland to routinely measure indoor pollutant exposure in a statistically valid sample of buildings (like existing observatories in France or the US). The last representative survey of IAQ in 876 English homes was conducted by BRE in 2001 (Coward et al. 2001). As such, very limited UK/Ireland specific evidence exists to examine historical trends in indoor pollution exposure or its significance relative to outdoor air (Lewis, 2022; Holgate et al. 2020). As highlighted by Lewis et al. (2022 ,p.13), '*There is an urgent need to establish a national baseline assessment of indoor air quality across the UK in both heating and non-heating seasons*.'

2 MONITORING STANDARDS AND GUIDANCE

Key questions need to be addressed to establish a long-term national monitoring programme to inform policy, for instance: i) Which pollutants should be monitored and for how long, ii) Where do we place sensors, iii) Which validation and calibration methods should be applied, iv) What contextual data is required, v) What format should data be stored in, vi) How should the data be processed and managed? There is a particular need to identify the types of behavioural data required and to evaluate the most effective (and acceptable) means to capture this.

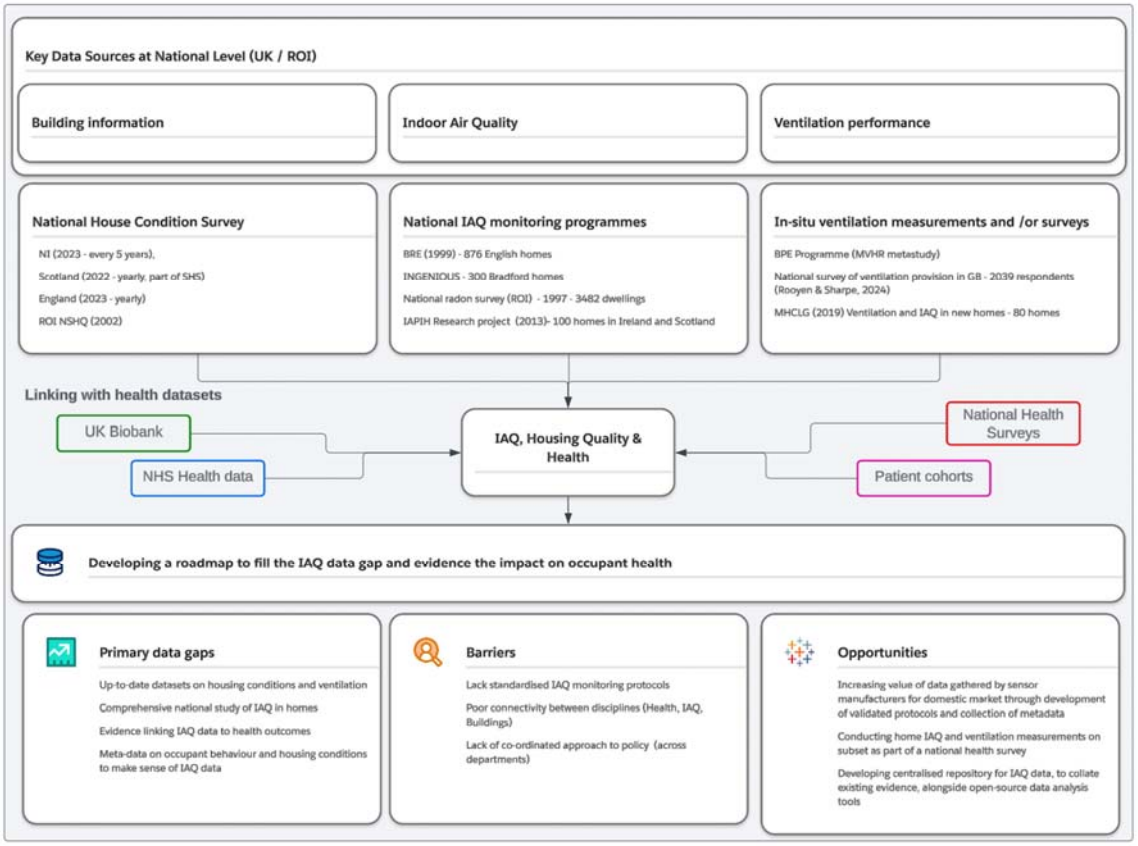
BS 40101:2022 provides limited guidance on sensor placement (e.g. min distances from radiators, windows, ventilation terminals etc.) and recommends calibration in accordance with manufacturer's recommendations. EPA (2022) provides key considerations when placing IAQ sensors, including i) security, ii) power, iii) access, iv) take photos, v) documentation, vi) communications and vii) placement. Whilst these guidance documents are useful, there is a need for standardized protocols for large-scale, nationally representative monitoring programmes. In 2002, BRE proposed a draft protocol for assessing IAQ in homes and offices, however updated guidance is considerably lacking.

3 CONNECTING DATASETS: A ROADMAP TO FILLING THE IAQ DATA GAP

Greater support for multidisciplinary research is essential to gather high-quality evidence that tracks building ventilation, IAQ and health, which will require a coordinated approach to monitoring and management at a national level. This should include activity-based emissions inventories, which are fundamental to underpin modelling of indoor pollution levels (Lewis et al. 2022). Moreover, new strategies and tools are needed for research-led measurements to

develop better process-level understanding of IAQ, including further research to ensure data quality from low-cost sensors (Lewis et al. 2022).

Figure 1: A roadmap to filling the IAQ data gap



4 FUTURE RESEARCH DIRECTIONS AND OPPORTUNITIES

The significant increase in measurement and availability of IAQ data through low-cost sensor development and SMART building systems represents a significant opportunity for data sharing, however validated measurement strategies and detailed metadata is essential to derive value from this data. A centralised repository for research-led IAQ monitoring campaigns would support collation of existing evidence. Moreover, the development of open-source tools for the analysis and visualisation of IAQ data, including tools to support validation and calibration of the data would significantly enhance research in this field.

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