Indoor air quality post deep energy retrofit in social homes in Ireland (HAVEN)

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SUMMARY

Improving the energy performance of a building has been shown to improve health outcomes in fuel poor homes (Wang et al., 2022). However, increasing building air tightness through provision of increased insulation, without due regard to building ventilation, can result in poorer air quality and impaired health for residents, in particular impaired respiratory health (Wimalasena et al., 2021; McGill et al., 2015; Ferguson et al., 2020). The Health Impact Assessment of Energy Renovations on Irish Domestic Dwellings (HAVEN) research project aimed to study the health impact and associated benefits of energy renovation among Irish social housing. This paper summarises the indoor air quality measurements collected in a sample of Irish social housing properties pre and post-energy retrofit. Our research suggests that occupant behaviour such as blocking wall vents and smoking have the potential to negatively impact on indoor air quality. In order to optimise the co-benefits of energy retrofit to IEQ in social housing, renovation needs to include an effective communication strategy, with targeted messaging to tenants on indoor air quality and its relationship with health.

KEYWORDS

Indoor air quality, ventilation, social housing, $PM_{2.5}$, formaldehyde

1.0 METHODOLOGIES

A total of 14 homes participated at pre- and post-retrofit stage, including 11 social housing properties and 3 private dwellings. Within the main living area and main bedroom of each home the following indoor environmental parameters were monitored; temperature (°C), relative humidity (%), carbon monoxide (ppm) (measured at 5-min intervals for 48-72 hours using GrayWolf IAQ-610 sensing probes), $PM_{2.5}$ (µg.m^3) (measured at one-minute intervals for 48 hours using a TSI SidePak AM520), formaldehyde (µg.m^3) (UMEX passive sampler for 3 days) and radon (Bq.m^3) (Radtrak closed alpha-track detector for 3 months). If mechanical ventilation systems were installed, they were also assessed. During the survey participants were asked to complete a short questionnaire to record information such as occupant demographics, typical household activities, space heating and ventilation methods. Participants were also asked to complete an activity diary to document household activities that may have influenced indoor air quality e.g., cooking activities, burning incense. Ventilation rates were calculated using bedroom night-time (10 pm-7 am) CO_2 data using the steady-state method (Persily & de Jonge, 2017). Project data was collated using Microsoft Excel and analysed using R statistical software. The impact of the retrofit on air quality was analysed using t-tests and linear mixed effects models in R.

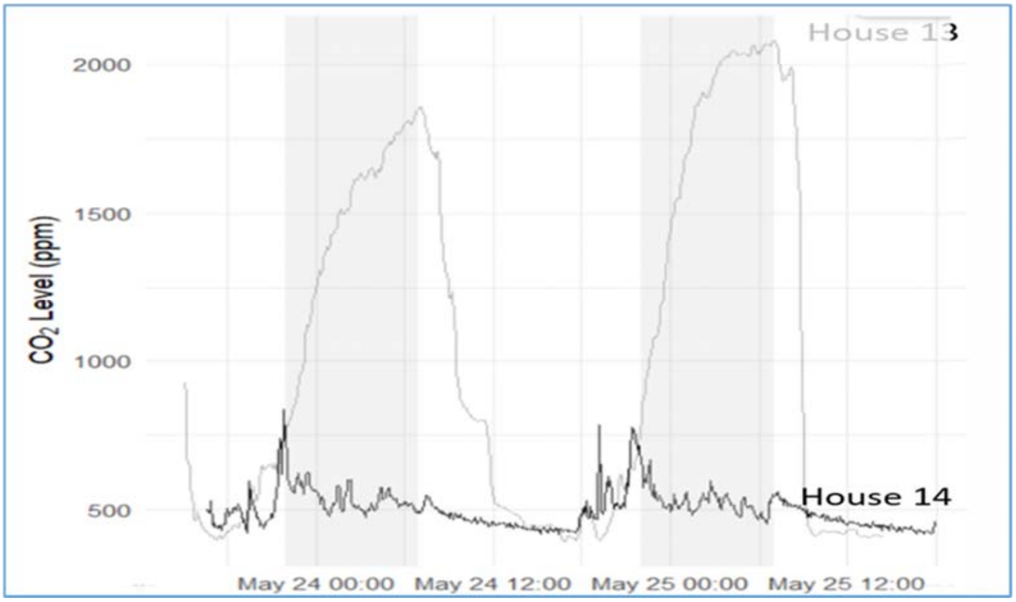

Figure 1. Time series plot of carbon dioxide concentrations during the nighttime period in a home with blocked wall vents (House 13) and unblocked wall vents (House 14).

2.0 RESULTS AND DISCUSSION

All homes had a significant energy uplift post-retrofit. Fossil fuel-based heating systems were replaced with a heat pump, some homes received extra wall and/or attic insulation, and new energy efficient windows or doors. The three private homes, and two of the social housing properties had demand control ventilation systems installed. Post-retrofit median air temperatures were within EN16798 Category I limits, and respondents reported less thermal discomfort due to draughts. Post-retrofit median CO_2 concentrations were lower in mechanically ventilated homes in comparison with the naturally ventilated homes and bedroom ventilation rates were higher in mechanically ventilated dwellings (up to 5.0 $L.s^{-1}.p$ in naturally ventilated homes compared to up to 12.0 $L.s^{-1}.p$ in mechanically ventilated dwellings). Analysis of the indoor concentrations of carbon dioxide and $PM_{2.5}$ highlighted the impact of occupant behaviour on indoor air quality. Blocked wall vents were observed in 45% of the social housing properties, which resulted in higher CO_2 concentrations particularly in bedrooms (median value of 1425 ppm versus 859 ppm in bedrooms with and without blocked wall vents respectively). Figure 1 compares the nighttime bedroom CO_2 concentration in the main bedroom (occupied by two persons) of two identical homes, surveyed during the same period. The concentration profile for Home 13 shows the impact of blocked wall vents on CO_2 concentration compared to Home 14 which had unblocked wall vents. Smoking and or vaping was observed in four social housing properties, and levels of $PM_{2.5}$ in such homes were higher than the WHO 24-hour guideline value of 15 $\mu g/m^3$ (WHO, 2021) both pre and post- retrofit. $PM_{2.5}$ concentrations in smoker homes (median value of between 56–58 $\mu g/m^3$) are within the range of those reported previously for smoking residences (Semple et al., 2015), and in the presence of lower ventilation post retrofit, presents an increased risk of $PM_{2.5}$ exposure post retrofit. Formaldehyde concentrations increased post retrofit, similar to observations from previous studies on indoor air quality in energy retrofits (Hassan et al., 2024).

3.0 CONCLUSION

Our research suggests that occupant activities such as blocking wall vents and smoking indoors have the potential to negatively impact on indoor air quality in social housing retrofits. As part of the ventilation strategy for social housing efforts are required to consult with tenants to determine factors contributing to occupant behaviours leading to poor indoor environmental quality. Considering the vulnerability of the residents of many social housing properties, it is imperative that retrofit does not negatively impact on indoor air quality.

4.0 ACKNOWLEDGEMENTS

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