Estimating the health impact of exposure to indoor $PM_{2.5}$ concentrations in Irish deep energy retrofitted residential dwellings – ARDEN

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SUMMARY

Maintaining good indoor air quality (IAQ) post energy retrofit is essential to ensure the health and wellbeing of building occupants. In this study, a number of indoor air pollutants were measured in a sample of Irish homes pre and post deep energy retrofit (DER). Airborne concentrations of $PM_{2.5}$ and formaldehyde showed significant increases ($p < 0.0001$) post-retrofit. A health impact assessment was conducted and the results suggest that the greatest health burden (for lung cancer and all-cause mortality) was associated with exposure to $PM_{2.5}$.

KEYWORDS

Energy Retrofit, Indoor air quality, Particulate Matter ($PM_{2.5}$), Health Impact Assessment

1 METHODOLOGY

$PM_{2.5}$, CO_2, CO, TVOC, formaldehyde, temperature and relative humidity were measured over a period of 24-72 hours in the bedrooms and living rooms of 11 homes (pre-post retrofit) and 14 homes (post retrofit only). Radon was also measured in the same rooms post retrofit for a period of 3-9 months. All homes had participated in the SEAI DER pilot programme and were upgraded to a minimum building energy rating (BER) of A3 following retrofit. A summary of building characteristics and details on the measurement campaigns and equipment used have been published [1, 2].

The homeowners completed an activity diary during the measurement period to inform possible pollution sources, and a questionnaire survey to collect information about the dwelling, occupant behaviour, thermal comfort and overall satisfaction with the retrofit. Pre retrofit, all homes were naturally ventilated and mechanical ventilation was installed in all homes as part of the retrofit. Survey data was collated using a spreadsheet application (Microsoft Excel) and further data analysis was carried out using R statistical software. In our analysis we assumed that the living rooms are likely to be occupied during the daytime (7:00 – 22:00) while bedrooms are occupied during the night-time (22:00 – 7:00). We used linear mixed-effects models (LMEs) and performed t-test calculations to determine the impact of the retrofit.

A health impact assessment was conducted to estimate the change in health burden due to retrofit from exposure to $PM_{2.5}$, formaldehyde, and radon. The health impact analysis was performed using baseline data from 2019 to exclude the impact of the Covid19 pandemic. Concentration-response functions (CRFs) [3], linking the change in the incidence of disease in a population with the change in exposure in pollutant level, were used to calculate the health burden of certain health end-points (Table 1) known to be associated with the selected pollutants. For time-series data, such as the case with $PM_{2.5}$, we used the 24-hr time weighted average (TWA) based on daytime concentrations for the living rooms and night-time concentrations for the bedrooms. For formaldehyde, we used the 72-hr averages for bedrooms and living rooms, and for radon we used the overall average over the measurement period. Population data and background rates of disease for Ireland were taken from the Central Statistics Office Ireland and the National Cancer Registry Ireland [4, 5].

Table 1: A summary of the measured pollutants and the selected health endpoints and relevant concentration-response functions

Health endpoint	Pollutant	Risk function
All-Cause Mortality	$PM_{2.5}$	8.0 % per 10 µg m^{-3} $PM_{2.5}$ [3]
Lung Cancer	$PM_{2.5}$	9.0 % per 10 µg m^{-3} $PM_{2.5}$ [3]
	radon	8.4% per 100 Bq m^{-3} [6]
Leukaemia	radon	12.0% per 100 Bq m^{-3} [7]

2 RESULTS & DISCUSSION

The LME model showed that $PM_{2.5}$ increased significantly (p <0.0001) post retrofit (in the homes with pre-post data). $PM_{2.5}$ 24-hr average concentrations post retrofit in the bedrooms ranged from 4.8 µg m^{-3} to 310.6 µg m^{-3} and in the living rooms from 7.4 µg m^{-3} to 238.0 µg m^{-3}, and they exceeded the WHO daily guideline (15 µg m^{-3}) in 72% and 77% of the measured bedrooms and living rooms, respectively. For the 11 homes examined pre retrofit, formaldehyde showed a significant increase post retrofit (p <0.05) in both bedrooms and living rooms. The average formaldehyde concentrations post retrofit ranged between 12.0 µg/m^3 and 128.0 µg/m^3 (Figure 1). Figure 2 shows the average radon concentrations measured post retrofit in 18 homes. The overall average concentration across all homes (107.6 Bq m^{-3}) exceeded the Irish indoor average for residential buildings (77.0 Bq m^{-3}) and the pre-1998 average (89.0 Bq m^{-3}) [8].

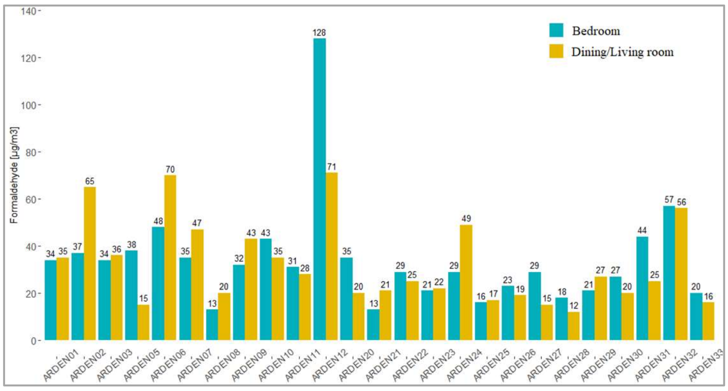

Figure 1: Formaldehyde concentration post retrofit in bedrooms and living rooms

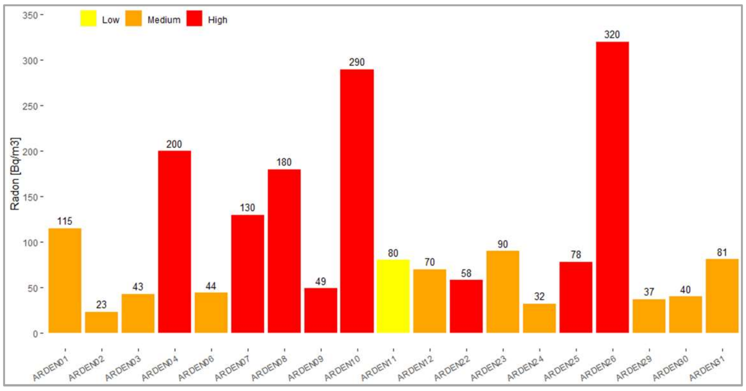

Figure 2: Radon average concentrations post-retrofit. Colours indicate low, medium, and high radon areas [9]

Preliminary results from the health impact assessment suggest that the greatest health burden is due to exposure to increased $PM_{2.5}$, followed by radon. For formaldehyde, we were not able to quantify any carcinogenic health effects as the measured post retrofit levels were below the concentrations at which health effects have been shown in other studies, which are typically based on highly exposed occupational cohorts [10]. The $PM_{2.5}$ data post retrofit was highly variable and increases should not be attributed to the retrofit alone, but are more likely due to a combination of sources including: ingress of outdoor $PM_{2.5}$ from residential combustion or traffic sources, indoor sources (e.g. cooking, wood burning stoves or burning scented candles) sometimes in the absence of good ventilation [11].

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