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Case study investigation of indoor air quality in mechanically ventilated and naturally ventilated UK social housing

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Abstract

There is a significant lack of indoor air quality research in low energy homes. This study compared the indoor air quality of eight newly built case study homes constructed to similar levels of air-tightness and insulation; with two different ventilation strategies (four homes with Mechanical Ventilation with Heat Recovery (MVHR) systems/Code level 4 and four homes naturally ventilated/Code level 3). Indoor air quality measurements were conducted over a 24 h period in the living room and main bedroom of each home during the summer and winter seasons. Simultaneous outside measurements and an occupant diary were also employed during the measurement period. Occupant interviews were conducted to gain information on perceived indoor air quality, occupant behaviour and building related illnesses. Knowledge of the MVHR system including ventilation related behaviour was also studied. Results suggest indoor air quality problems in both the mechanically ventilated and naturally ventilated homes, with significant issues identified regarding occupant use in the social homes.
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Keywords: Indoor air; Mechanical Ventilation with Heat Recovery (MVHR); Social housing; Code for sustainable homes; Energy efficient design

1. Introduction

There exists a significant need for indoor air quality research in contemporary energy efficient dwellings. As suggested by a number of recent reports, the impact of energy efficient design strategies on the quality of the indoor environment remains largely under-researched, with a worrying absence of skills and knowledge in this area (Crump et al., 2009; Innovation and Growth Team, 2010; Sullivan et al., 2012, 2013). This is despite research suggesting that the tightening of building envelopes, reduction of ventilation rates, use of new building materials and techniques with unknown consequences and reliance on technology to provide sufficient ventilation may significantly diminish the quality of indoor air.

In particular, studies are needed to compare indoor air quality in low energy dwellings with indoor air quality in otherwise similar non-low energy dwellings. As suggested

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by Mendell (2013), future research questions should focus on specific energy-related factors and compare buildings as alike as possible excluding the particular energy related factor under consideration. Numerous studies investigating the effects of energy efficient retrofits have been conducted, however similar studies investigating new buildings are significantly lacking. For example, a study by Less and Walker (2013) investigated indoor air quality in 17 mechanically ventilated and naturally ventilated deep energy retrofits. They found statistically indistinguishable air change rates between the two house types. Furthermore, a number of faults with mechanical ventilation systems were identified, including air recirculation, clogged outside air inlets, failed attachment of ducts to units, irregular speed fluctuating from low to high and poor control.

Studies investigating indoor air quality in energy efficient dwellings have also focused on apartments or detached homes as opposed to terraced/semi-detached homes (such as (Aizlewood and Dimitroulopoulou, 2006; Mickaël et al., 2014). For instance, a study by Noris et al. (2013) investigated the effect of energy retrofits on indoor environmental quality in sixteen apartments (eight with continuous mechanical ventilation and eight without). The findings suggest improvements in levels of carbon dioxide, VOC's, acetaldehyde, PM2.5, comfort conditions and bathroom relative humidity; however mixed results were reported for concentrations of formaldehyde and nitrogen dioxide. In general, apartments with continuous mechanical ventilation showed a greater improvement of indoor environmental quality (other than PM2.5) compared to those without.

Furthermore, social housing is generally under-researched despite the fact that low-income households are at increased risk of exposure to indoor air pollution (Chuang et al., 1999; Krieger et al., 2002, 2000). For example, a study by Fung et al. (2006) looked at the conflict between air quality and energy efficiency in social housing, with particular reference to occupant behaviour. The results suggest a risk of negative impact on health from indoor air pollution in the social housing sector. Similarly, a case study investigation of low energy social housing by Ward (2008) suggests recent changes to the UK building regulations on the provision of natural ventilation in dwellings do not ensure adequate supply of fresh air. The poor perception of ventilation by the social tenants was also highlighted.

Despite this, there remains a significant emphasis on energy efficiency and fuel poverty in the social housing sector, with limited attention to indoor air quality. For instance, there remains greater obligation on local authorities to adopt energy efficient design strategies for newly built housing projects and for the retrofitting of existing housing stock. Also, unlike owner-occupied newly built dwellings, the Homes and Community agency in the UK require newly built affordable/social housing to meet the Code for Sustainable Homes Level 3 or above (Department for Communities and Local Government, 2012). The effect however of the Code for Sustainable Homes on indoor air quality is significantly under-researched.

This study therefore aims to (1) investigate the indoor air quality of newly buillt social housing in a UK context and (2) compare the results of homes designed to meet the Code for Sustainable Homes (CSHs) level 3 (naturally ventilated) and level 4 (MVHR). This was conducted through physical indoor air quality measurements alongside occupant diaries, in eight newly built dwellings (4× Code level 3 and 4× Code level 4). Interviews were also conducted to gain information on occupants' perception of indoor air quality and thermal comfort, Sick Building Syndrome symptoms and occupant behaviour. Building surveys were conducted on the day of the measurements to record information on general building conditions. This paper discusses the methodological approach followed by presentation of results and discussion. Finally, conclusions and further research opportunities are described.

2. Methodology

A case study approach was adopted in order to gain a comprehensive understanding of indoor air quality in newly built social housing. This included an investigation on the effect of occupant behaviour on indoor air quality, the performance of MVHR systems and occupant knowledge of these systems, building related health and perception of indoor air quality in Code 3 and 4 homes.

The case study homes were selected based on a number of criteria: single family social housing, availability, terraced or semi-detached, newy built ($\geqslant$2010), similar location and similar levels of airtightness ($<5\ m^3/h\ m^2$). Each household was approached initially through the housing association, followed by a phone call to explain the study and a subsequent meeting. Simultaneous air quality measurements were then conducted in the main bedroom, living room and outside during the summer (July–August 2013) and winter (November 2013–January 2014) months. An occupant diary was employed during the measurements to gain information on occupancy levels and activities which may have influenced the results. For example, occupants were asked to record various activities such as opening windows, use of air polluting products, smoking, cooking, use of boost mode function (if applicable), opening of internal doors and measurement room/household occupancy each hour. The diary was condensed to one A4 page for each measurement day.

Physical indoor air quality measurements were conducted in the main living room and bedroom at a height of approximately 1.1 m above the finished floor level, in accordance with ISO: 16000-1. Parameters included temperature, relative humidity and carbon dioxide which were monitored in the living room with an Extech IAQ datalogger (Easyview EA80-RH resolution 0.1%, accuracy ±3–5%, temperature resolution 0.1 °C, accuracy ±0.5 °C,

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