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Review article

Impact of climate change on the domestic indoor environment and associated health risks in the UK

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ABSTRACT

There is growing evidence that projected climate change has the potential to significantly affect public health. In the UK, much of this impact is likely to arise by amplifying existing risks related to heat exposure, flooding, and chemical and biological contamination in buildings. Identifying the health effects of climate change on the indoor environment, and risks and opportunities related to climate change adaptation and mitigation, can help protect public health.

We explored a range of health risks in the domestic indoor environment related to climate change, as well as the potential health benefits and unintended harmful effects of climate change mitigation and adaptation policies in the UK housing sector. We reviewed relevant scientific literature, focusing on housing-related health effects in the UK likely to arise through either direct or indirect mechanisms of climate change or mitigation and adaptation measures in the built environment. We considered the following categories of effect: (i) indoor temperatures, (ii) indoor air quality, (iii) indoor allergens and infections, and (iv) flood damage and water contamination.

Climate change may exacerbate health risks and inequalities across these categories and in a variety of ways, if adequate adaptation measures are not taken. Certain changes to the indoor environment can affect indoor air quality or promote the growth and propagation of pathogenic organisms. Measures aimed at reducing greenhouse gas emissions have the potential for ancillary public health benefits including reductions in health burdens related heat and cold, indoor exposure to air pollution derived from outdoor sources, and mould growth. However, increasing airtightness of dwellings in pursuit of energy efficiency could also have negative effects by increasing concentrations of pollutants (such as $PM_{2.5}$, CO and radon) derived from indoor or ground sources, and biological contamination. These effects can largely be ameliorated by mechanical ventilation with heat recovery (MVHR) and air filtration, where such solution is feasible and when the system is properly installed, operated and maintained. Groups at high risk of these adverse health effects include the elderly (especially those living on their own), individuals with pre-existing illnesses, people living in overcrowded accommodation, and the socio-economically deprived.

A better understanding of how current and emerging building infrastructure design, construction, and materials may affect health in the context of climate change and mitigation and adaptation measures is needed in the UK and other high income countries. Long-term, energy efficient building design interventions, ensuring adequate ventilation, need to be promoted.

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Contents

1. Introduction

Growing scientific evidence indicates that climate change is likely to cause a range of direct and indirect effects on dwellings (Crump, 2011; IOM, 2011). People in developed countries typically spend over 90% of their time indoors (Harrison et al., 2002; Vardoulakis, 2009; Lai et al., 2004). In the UK, a study of activity patterns in Oxford found participants were spending an average of 95.6% of their time indoors, with 66% of their time spent in their homes (Schweizer et al., 2007). Furthermore, vulnerable individuals in Europe (the elderly, young children, and people with compromised health) may spend an even larger proportion (up to 100% of their time) at home (Glorieux et al., 2002; Torfs et al., 2008). It is therefore important to consider the degree to which climate change impacts on the indoor environments affect the physical and mental health and wellbeing of dwelling occupants.

Buildings account for a large proportion of energy consumption and greenhouse gas (GHG) emissions in high income countries. In the UK, residential buildings were responsible for around 25% of total GHG end-user emissions in 2012 (DECC, 2014). The UK Government is committed to an 80% reduction (from the 1990 baseline) in GHG emissions by 2050 (DCLG, 2010). Therefore, policies to mitigate and adapt to climate change in the domestic sector can play a key role in attaining this goal (Bone et al., 2010).

Although building structures are primarily intended to provide shelter and enhance wellbeing, they are also associated with a range of health hazards, such as those attributable to indoor air pollution, extreme temperatures, pests and infestations, noise, airborne infectious diseases, water or mould contamination, domestic injuries and poisoning, and mental health effects (Haines et al., 2007; Mcmichael, 2011; WHO, 2011). The form of the built environment (e.g. urban density) may also have influence on factors relating to "life-style" diseases, such as cardiovascular illness. Health inequalities can also be aggravated or mitigated by housing conditions (BMA, 2003; House of Commons, 2009; Shrubsole et al., 2015).

A number of papers have recently reviewed how climate change and mitigation and adaptation measures may affect the indoor environment, including building overheating, indoor air quality and biological contamination, mainly focusing on high-income countries (IOM, 2011; Spengler, 2012; Nazaroff, 2013). In the UK context, there has been substantial research mainly on the impact of climate change on building overheating, as well as on the relevant adaptation and mitigation measures (e.g. CIBSE, 2005; Hacker et al., 2005; Capon and Oakley, 2012; DCLG, 2012a; De Wilde and Coley, 2012; NHBC Foundation, 2012). Studies have also focused on the impacts of climate change mitigation and adaptation on indoor air quality (Shrubsole et al., 2012), and highlighted research needs in this area (Crump, 2011). There is a particular need for an improved understanding of the performance of highly energy efficient homes under climate change scenarios, the quality of their ventilation systems, and the impact on health and wellbeing of their occupants (Dimitroulopoulou, 2012; Wargocki et al., 2002; Crump et al., 2009).

In this paper we provide an overview of the interaction of climate change, the domestic indoor environment and health in the UK, focusing on (i) building overheating and thermal comfort, (ii) indoor air quality, (iii) indoor allergens and infections, and (iv) flood damage and water contamination. The discussion includes unintended harmful effects of climate change mitigation and adaptation policies, as well as opportunities for health protection and health promotion.

2. Overheating of buildings and thermal comfort

Temperatures on the Earth's surface have risen for each of the last three decades and are now higher than in any previous decade since 1850 (IPCC, 2013). In the UK, temperatures have increased since pre-industrial times, and at a rate of around 0.25 °C per decade since the 1960s (Vardoulakis and Heaviside, 2012). Central estimates of climate projections for the UK (UKCP09; Murphy et al., 2010) indicate increases in the summertime mean daily maximum temperatures up to 5.4 °C in southern England, and up to 2.8 °C in northern Britain by 2080, under a medium GHG emissions scenario. Heatwaves are also likely to become more frequent and intense in future decades (Jones et al., 2008).

The association between elevated outdoor temperatures and mortality has been extensively reported (e.g. Hajat et al., 2014; Armstrong et al., 2011; Vardoulakis et al., 2014). The elderly, people with pre-existing medical conditions (e.g. mental disorders, neurological or cardiovascular disease) and those who are overweight or have reduced mobility, are likely to be more vulnerable during prolonged hot periods and heatwaves (Haines et al., 2007; Hajat et al., 2007).

The European heatwave of August 2003, considered to be the most intense since 1500 (Luterbacher et al., 2004), has been estimated to have caused up to 70,000 additional deaths in Europe (Robine et al., 2008). In the UK, there were over 2000 excess deaths (a 17% excess