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The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom

James D. Miller*, Michael Hutchins

Centre for Ecology and Hydrology, Crowmarsh Gifford, Oxfordshire, OX108BB, United Kingdom

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ABSTRACT

Study region: United Kingdom (UK).
Study focus: Climate change and urbanization pose significant threats for flooding and water quality in urban areas. This paper reviews the evidence concerning the combined impacts of urbanisation and climate on the urban water environment of inland catchments of the United Kingdom and assesses the degree of confidence in reported directions of change and response. It also assesses the utility of the evidence for setting environmental legislation and managing the urban water environment in the future and identifies knowledge gaps that limit effective and management interventions.
New hydrological insights: There is a lack of nationally research focused on the dual impacts of climate change and urbanisation on flooding and water quality in UK urban areas. This is despite there being a clear acceptance that flood risk is increasing, water quality is generally not meeting desirable levels, and that combined population and climate change projections pose a pressing challenge. The available evidence has been found to be of medium-high confidence that both pressures will result in (i) an increase in pluvial and fluvial flood risk, and (ii) further reduction in water quality caused by point source pollution and altered flow regimes. Evidence concerning urban groundwater flooding, diffuse pollution and water temperature was found to be more sparse and was ascribed a low-medium confidence that both pressures will further exacerbate existing issues. The confidence ascribed to evidence was also found to reflect the utility of current science for setting policy and urban planning. Recurring factors that limit the utility of evidence for managing the urban environment includes: (i) climate change projection uncertainty and suitability, (ii) lack of sub-daily projections for storm rainfall, (iii) the complexity of managing and modelling the urban environment, and (iv) lack of probable national-scale future urban land-use projections. Suitable climate products are increasingly being developed and their application in applied urban research is critical in the wake of a series of extreme flooding events across the UK and timely for providing state-of-the-art evidence on which to base possible future water quality legislation in a post Brexit-WFD era.

1. Introduction

The United Kingdom has a significant legacy of urban development and associated deterioration of the urban water environment

* Corresponding author.
E-mail addresses: millj@ceh.ac.uk (J.D. Miller), mihu@ceh.ac.uk (M. Hutchins).

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which only began to improve with technology and environmentally focused legislation in the latter 20th C (Johnstone and Joran, 1996). Poor urban water quality continues to be a concern, especially with increasing population growth, the growing presence of new and un-controlled substances (Vörösmarty et al., 2010), a greater value attributed to ecosystem services (Green et al., 2015), and uncertainty over the impacts of climate change on controlling factors of water quality such as temperature and environmental flows (Acreman and Ferguson, 2010; Arnell et al., 2015).

Flooding of urban areas poses one of the greatest challenges to human safety and sustained economic growth within the UK with estimated expected annual damages from flooding of £1bn (Hall et al., 2005) and costs from recent flooding during the winter of 2015–2016 in excess of £5bn (KPMG, 2016). Changes to the timing and magnitude (depth) of rainfall events as a result of climate change are predicted to significantly alter the flooding experienced in many urban areas of the world including the UK and without suitable mitigation lead to increased future flood risk and associated damages (Ashley et al., 2005; Wheater and Evans, 2009). Recent widespread flooding across the UK during the winter storms of 2013/14 (Muchan et al., 2015) and 2015/16 (Priestley, 2016) have highlighted the significant impacts that flooding can have.

A number of studies and reviews have approached the topic of climate change and urban water environment impacts at the global scale (e.g. Praskievicz and Chang, 2009; Hunt and Watkiss, 2011; Kundzewicz et al., 2013), highlighting the challenges posed by a combination of climate change and rapid urban development. Additionally, a number of UK focused reviews exist assessing climate impacts upon the water environment in general (e.g. Watts et al., 2015; Arnell et al., 2015; Whitehead et al., 2013; Wilby, 2008; UK Met Office, 2011). What is lacking and currently required − given the need to appraise the existing evidence in light of potential changes to environmental legislation as a result of the UK leaving the European Union (Brexit) − is a review of the evidence concerning the urban environment in the UK. The aim of this paper is to assess the evidence concerning the current and future combined impacts of urbanisation and climate change on the urban water environment of inland catchments in the United Kingdom and the degree of confidence in reported directions of change and response. The coastal urban environment is subject to a wider range of climate and urbanisation related issues, and being well reviewed elsewhere (Hall et al., 2006) is not considered in this review. The paper first provides an overview of the pressures of urbanisation and climate change in the UK. It then undertakes an assessment of UK focused literature on both urban flooding and urban water quality, looking at current and future pressures. It additionally assesses confidence in the relevance and quantity of evidence reported for changes to the water environment. This assessment is used to assess the utility of the existing evidence for managing the urban water environment in the future. Conclusions are drawn concerning the current evidence and knowledge gaps are identified.

2. Urbanisation, urban water management, and climate change in the UK

Over 80% of the population in Britain live in urban areas and the population of the UK has risen from 32 million in 1901–64.6 million in 2014 (ONS, 2014). Significantly, the United Kingdom is one of ten countries with over 5% (5.7%) of total land area occupied by cities (Angel et al., 2011) and is set to undergo a period of extensive population growth to 74.3 million (15%) by 2039 (ONS, 2014) and extrapolated to 97.2 million (+53%) by the 2080 s (Sayers et al., 2015). This requires more than just expansion and intensification of existing urban areas, and the UK government is currently planning a number of new 'garden' towns and villages.

Flood management in the UK is based on the concept of risk analysis, with the likelihood of flooding assessed using an annual exceedance probability (AEP) such as the 1% AEP (1 in 100 year event) and consequence assessed according to hazard and the magnitude of consequences. The Department for Environment Food and Rural Affairs (Defra) has government oversight for policy, while the Environment Agency (EA − England and Wales) and Scottish Environment Protection Agency (SEPA − Scotland) are the implementing authorities charged with making detailed assessments and management of national and regional flood risk. Additionally private water companies, local councils, highway authorities and internal drainage boards have responsibilities for sewer systems, storm drainage, main roads, and low lying farmland respectively (Bubeck et al., 2013). 2.4 million properties are at risk of flooding from rivers and the sea, with the majority in urban areas (Environment Agency, 2009) whilst pluvial flooding is the largest cause of property flooding in UK, with an estimated 3.8 million properties at risk (Environment Agency, 2009), accounting for around 40% of flood damage (Defra, 2014). Estimates for groundwater flooding in the United Kingdom are variable, with figures indicating properties at risk ranging from 122,000 and 290,000 (McKenzie and Ward, 2012) to 1.6 million (Jacobs, 2004).

The maintenance of river water quality is controlled under the EU Water Framework Directive (2000/60/EC) for which water-body-specific targets are stipulated in terms of ecological status. In England and Wales, the EA is the designated competent authority charged with monitoring, reporting and enforcement, while for Scotland it is SEPA, where the WFD is legislated under the Water Environment and Water Services (Scotland) Act 2003 (WEWS act). Identification of reasons for failure and programmes of measures to rectify non-conformity is undertaken in iterative cycles. Nationally around 75% of waterbodies currently fail to meet good ecological status although the situation is improving (Priestley, 2015). Urban influences may be dominant in governing the condition of waterbodies (e.g. effluents), especially in small waterbodies (McGrane et al., 2016). In this regard, control of hazardous substances through wastewater treatment and improvements to sewerage infrastructure are commonly implemented measures.

Climate projections for the UK are provided by the latest generation of the UK Met Office Hadley Centre regional climate model (RCM) projection scenarios − UKCP09 − and indicate the 21st C will have wetter, warmer winters (mainly to the north and west) and hotter, drier summers (mainly in the south and east) but with variable change predicted under emission scenarios and probability level (Murphy et al., 2010 − Fig. 1). This spatial and temporal variability across a relatively small island nation is not shown in global climate models (IPCC, 2014) and exemplifies why it is important to consider climate change at refined spatial and temporal scales using RCMs when assessing impacts on hydrological processes within relatively small (by international standards) catchments and defined urban areas.