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Original Research

An attempt to quantify the health impacts of flooding in the UK using an urban case study

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Summary *Objectives:* To quantify, so far as possible, the health effects of flooding in the UK to allow comparison between different flooding events.
Methods: The health effects resulting from flooding events were determined through an extensive literature search, where information existed to enable the quantification of these effects. Disability-adjusted life years (DALYs) were used to enable the comparison between different health impacts and different flood events and populations, using two sites subject to pluvial flooding in the Bradford area, UK.
Results: Relatively few properties (and hence people) were affected by flooding in the case study areas and there were no predicted deaths or serious injuries; these results were supported by anecdotal knowledge of the events. Mental health problems, characterized as psychological distress, were estimated for adults; these were found to dominate the calculated health impacts, being considerably greater than the combined physical symptoms in the case study examples.
Conclusions: While it was not possible to quantify every flood-related health impact, this method does allow comparisons to be made between different flood events and mitigation strategies.

Introduction

As a result of the Easter floods of 1998, the widespread flooding occurring in recent winters and the extensive summer flooding of 2007, flooding has become very topical in the UK and it has moved up on both political and research agendas. Much of this interest may be due to the perception that climate change is leading to an increase in the occurrence and magnitude of extreme flood events,[1] and that the problem is not going to go away.[2]

While the devastation to properties is usually obvious following a flood event, the impacts on people (where drowning and serious injury does not occur) can be more subtle. Assessment of the

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health impacts of flooding, however, cannot generally be achieved through controlled prospective epidemiological studies, for obvious reasons. Thus, much of the literature is based on opportunistic retrospective studies of flooding case studies or anecdotal evidence.

The research reported in this paper was carried out as part of a project funded by the Engineering and Physical Sciences Research Council on adaptable urban drainage (Audacious GRS 18908/01). The research sourced literature information on flooding and health, with particular reference to studies that quantified the impact of flooding, to underpin two urban case studies of flooded areas in Keighley (part of the Bradford Metropolitan District Council area), UK.

Methods

Literature review

The literature review on flooding and health was conducted by searching a number of web-based databases (including Pubmed) and websites (including those of the Environment Agency (EA) and the Department of the Environment; Food and rural affairs (DEFRA)) for keywords; Including 'flood' and 'health'; 'drowning' and 'flood'; 'injury' and 'flood' etc. Bibliographies of identified papers were searched for additional relevant references.

No geographical restrictions were placed on the literature review, although foreign language databases were not interrogated and, generally, only English language papers were obtained for further review.

Background information on each of the identified health impacts was sought from a variety of sources. Data on possible quantification was, where possible, extracted directly from the flooding literature, and details relating to disability-adjusted life years (DALYs; see Quantification below) were established by literature review and direct contact with World Health Organization personnel.

Quantification

The aim of the flooding assessment was, where possible, to quantify the individual health outcomes as DALYs. These could then be summed to provide an overall assessment of the flood and enable comparison between different events.

DALYs are summary measures of health that allow comparison of effects across a wide range of health outcomes, including both mortality and morbidity. This means that, in the flooding context, deaths due to drowning or injuries related to a flood event can be combined with other health impacts, such as gastrointestinal upset and mental health impacts, enabling comparision of different actual flood events or flood scenarios.

The measure combines years of life lost by premature mortality with years lived with a disability (YLD), standardized using severity or disability weights. The weights range from 0 (perfect health) to 1 (dead). The measure was derived to use in the ongoing Global Burden of Disease Study, which aims to compare DALYs resulting from various illness and environmental risk factors (such as unsafe sanitation) across global regions.[3,4] As such, it uses a standard life expectancy at birth of 80 years for men and 82.5 years for women, and DALYs are discounted at 3% and age weighted.[5] For the purposes of this study, figures from the interim life tables for England of 76.2 for men and 80.72 for women (rounded to 76 and 81, for simplicity) were used,[6] with no discounting or age weighting. Disability weights have been derived for a number of disease categories.[7,8] Where possible, these have been used directly. Where severity weights have not been derived previously, these have been extrapolated from similar illnesses. Data on the likely duration of injuries and illness were derived from the literature.

The quantification of health impacts is based principally on:

- 'Flood risks to people' research project[9,10] for estimates of deaths and serious injuries; and
- World Health Organization methodology, adapted from the comparative risk assessment calculations of global disease burden,[11] which combines incidence in the general population with relative risk values derived from the literature.

Figures generated from each of these components were converted into DALYs by combining the estimates with figures for severity and duration, as outlined above.

Case studies

Two case study locations (Utley and Devonshire Park) in Keighley have been used. The areas were initially defined by Tony Poole (Bradford Metropolitan District Council) and John Blanksby (Pennine

Table 1 Profile of case study areas.

Area	No. of households	Population	No. of households flooded	Flood characteristics		
				Depth (m)	Velocity (m/s)	Return period (years)
Utley (Hollins Lane)	108	261	12	0.1	1.5	10
Utley (Beechcliffe)	94	226	8	0.1	1.5	10
Devonshire Park	186	553	10	0.1	1.5	10

Water Group) according to locations where pluvial flooding had occurred within the last 5 years.

A sociodemographic profile for each case study location was created using the 'Maps and Stats' website (http://www.mapsandstats.com), which allows incomplete output areas to be combined from user-defined areas (providing either a certain number of houses are selected or a target population is achieved to maintain the individual anonymity provided by output areas). Table 1 summarizes the profile of the case study areas. The Utley area was subdivided as the two flooded areas proved to have quite different sociodemographic profiles.

Health effects

Research into the health effects associated with flooding and the number of health reviews conducted[12–14] seems to have increased relatively recently, perhaps driven by the increase in flooding seen during the 20th Century[15] and the forecast from climate change modelling that this trend will continue.[16] In the UK, research is being sponsored by a number of agencies, including DEFRA and the EA as part of their joint Flood and Coastal Defence Research and Development Programme, and includes a major study into health (particularly mental health) and flooding, conducted in over 1500 homes in England and Wales.[17]

The health effects relating to flooding are generally split into those associated with the immediate event (with drowning being the most obvious) and those arising after the flood has resolved, i.e. post-onset, which may be related to exposure to flood waters, the clear-up process, or stress and anxiety. Health impacts can also be considered to be direct or indirect, with indirect impacts perhaps resulting from damage to infrastructure, food supply, etc. Indirect impacts are not considered in this paper, except in the consideration of flooded properties with private water supplies.

Health effects have been categorized into a number of groups, namely:

- mortality and injuries;
- other physical effects (including infection); and
- mental health effects.

The health effects for which data are currently available to allow quantification are summarized in Table 2, along with the relevant measures to allow quantification. A full discussion on individual health impacts and the references used to derive the data can be found in Fewtrell and Kay.[21]

These figures were then applied to the case study populations.

Results

As both case study areas only have a small number of properties that are typically flooded, relatively few people are affected and, thus, health impacts, in terms of DALYs, are correspondingly small. The results are summarized in the following sections.

Deaths and serious harm

No actual deaths or cases of serious harm are predicted to occur from the number of properties flooded and the depths and velocities of the water during the flooding events. This supports anecdotal knowledge from the events. For the Utley case study area, where 20 properties were estimated to have been flooded, affecting 48 people, the flood risk to people formula[10] provides an estimate of 0.3

Table 2 Health impacts and quantification measures.

Impact	Baseline incidence rate	Severity weighting	Assumed duration (days)	Relative risk	Reference[a]
Death	Figures for deaths are calculated from the flood risks to people formula, assuming an average life expectancy of 78.5 years. The age at death (due to a flooding incident) is taken as the average age for those living in the area.				10
Serious injury	–	0.372	56	–	10
Minor injury	–	0.05	7	–	18
Worsening of asthma (adults only)	0.076	0.07	7	3.1	19
Gastrointestinal illness	0.02	0.09	3	2.36	20
Earache	0.001	0.09	3	2.2	19
Mental health (adults only)	0.155	0.065	365	4.1	19

[a]References are for the source of the relative risk values or the key paper relating to quantification of the health impact.

Table 3 Physical symptoms.

Area	Minor injuries		Asthma (worsening)		Gastrointestinal illness		Earache	
	n	YLD	*n*	YLD	*n*	YLD	*n*	YLD
Utley (Hollins Lane)	1.7	0.002	3.8	0.005	0.8	0.0006	0.03	0.00002
Utley (Beechcliffe)	1.2	0.001	2.4	0.003	0.5	0.0004	0.02	0.00002
Devonshire Park	1.8	0.002	3.5	0.005	0.8	0.0006	0.03	0.00003

YLD, years lived with disability.

serious injuries and 0.0014 deaths, resulting in 0.08 DALYs.

Physical symptoms and mental health problems

Table 3 outlines the number (or fraction) of people affected and the corresponding YLD score for both case study areas for physical symptoms.

Mental health problems, characterized as psychological distress, were estimated for adults. Due to the long duration of these problems, the YLD scores were greater than those for the combined physical symptoms outlined above, with 0.582 being estimated for Utley and 0.332 estimated for Devonshire Park.

Overall health impact

Table 4 outlines the estimated DALYs as a result of flooding in the case study areas.

Discussion

To the authors' knowledge, this is the first attempt to quantify a wide range of health impacts resulting from flooding using DALYs, with the advantage of being able to compare the health burden caused by different flooding-related health impacts clearly, and also the possible effects of different remediation strategies (although that was not done in this case). The case studies used were based on small areas (populations between 226 and 553) with few flooded properties. However, the calculations could be applied to any flooded area and used to compare different events.

As noted earlier, the health impacts of flooding do not lend themselves to controlled epidemiological studies, and so much of the health information is derived from opportunistic retrospective reports. Routine surveillance data can be useful in determining episodes of infectious disease before and after flooding events, although this is, at best, a crude tool that under-records actual incidence of

Table 4 Health impact of flooding.

Area	Deaths (YLL)	Serious injuries (YLD)	Other physical symptoms (YLD)	Mental health symptoms (YLD)	Total (DALYs)
Utley (Hollins Lane)	0.03	0.01	0.006	0.36	0.405
Utley (Beechcliffe)	0.03	0.01	0.005	0.22	0.264
Devonshire Park	0.05	0.02	0.007	0.33	0.407

YLL, years of life lost; YLD, years lived with a disability; DALYs, disability-adjusted life years.

more minor illness.[22] As a result, it is generally not possible to obtain accurate information on disease incidence or prevalence before the flood, and it is likely that detection may increase after the flood because of enhanced surveillance activities, and bias the estimates. In addition, surveillance only captures a small proportion of actual illness as not everyone will seek medical advice, not all incidents will be reported to the authorities and, in many cases, the connection with a flooding episode may not be made. As a result, '*generally, there is very weak data available on non-drowning (non-immediate) deaths that can be attributed to the flood event*'.[2]

The risk values that have been derived from the literature and used in the estimation of health impacts could be site and/or flood-type specific. Although evidence suggests that the health impacts are similar irrespective of the type of flooding, the level of health impact may well vary. For example, gastrointestinal effects are likely to be greater as a result of flooding of an urban river with a waste-water treatment works input above the flooding point, compared with flooding caused by run-off from a more microbiologically pristine area.

There are limited data on the duration of most flood-related health impacts; therefore, this information has been drawn from the general medical literature. In some cases, 'indicator' conditions have been used in order to ascribe figures to both duration and severity and to simplify the calculation. In the case of serious injuries, for example, these have been assumed to be equivalent to a broken leg and ascribed a severity weight and duration accordingly. Where more detailed information is available, say for a specific flood event, the actual injuries sustained could be included in the DALY calculation.

In the case studies, relatively few people are affected by flooding; this means that, in many cases, the calculations give fractions for the number of deaths, injuries and illnesses. Clearly, it is impossible to have part of a death, but the calculations are meant to be indicative of the likely health impact of an event. Therefore, DALYs have been calculated irrespective of whether or not integers are returned.

It has not been possible to account for all known health impacts due to a lack of empirical data. Therefore, the total DALY score will not capture the entire health impact experienced by a community affected by a flooding event. However, the methodology presented here does allow different flood events to be compared for a number of specified impacts.

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Competing interests

None declared.

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