Health Climate Change impacts report card technical paper

9. Health Impacts of Climate Change: The Implications of Health and Social Inequalities

Jouni Paavola[1]

[1] Centre for Climate Change Economics and Policy (CCCEP), School of Earth and Environment, University of Leeds, Leeds, UK

Email: j.paavola@leeds.ac.uk

Key messages

1. Most evidence on vulnerability to and inequalities related to health impacts of climate change comes from observational studies focused on impacts. Little research exists on the implications of response strategies to address health impacts of climate change and more would be needed.
2. Climate change will have differential health impacts among different groups of people, because of differences in their exposure, sensitivity or/and adaptive capacity which together construe their vulnerability.
3. Older age, having pre-existing medical conditions and social deprivation are key attributes that make people vulnerable and lead them to experience more adverse climate change related health outcomes than others. However, there are also other attributes such as living in rural or urban locations, social isolation marginalisation and weak community cohesion that can dispose people as more vulnerable. When these attributes coincide they compound people's vulnerability.
4. In the future, climate change, aging population and decreasing public spending on health and social care can aggravate the inequality of health outcomes to do with climate variability and change.
5. Health education and measures to improve public preparedness that explicitly take into account differential exposure, sensitivity and adaptive capacity of different groups of people can help to address health and social inequalities to do with climate change.
6. Adaptation strategies based on individual preparedness and behaviour change may aggravate health and social inequalities to do with climate change due to their selective uptake, unless coupled with broad public information campaigns and financial support for undertaking adaptive measures.

1. Introduction

The Working Group II contribution to the Fifth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (IPCC) considers that by 2050 climate change will mainly exacerbate health problems that already exist, and that

populations that are currently most affected by climate-related diseases will also be at the greatest risk in the future (IPCC WG2, 2014). For example, health losses due to climate change-induced under-nutrition will mainly occur in areas that are already food-insecure (ibid.). But new conditions may also emerge under climate change**,** and existing diseases may extend their range into areas that are presently unaffected (ibid.). In the UK, the climate change impacts directly to do with health outcomes include for example increasing frequency and intensity of heat waves, extreme weather events and flooding, and changing ranges of disease vectors and parasites. But climate change can also have impacts on mental health and indirect health impacts for example via changing prices and availability of food (Morris et al, 2014).

The health impacts of climate change will not be the same for all groups and individuals in the society: they will vary because of the differential exposure, sensitivity and adaptive capacity of groups and individuals, which together constitute their vulnerability (Adger, 2006). Vulnerability plays a significant role in determining outcomes of climate change impacts. For example, some groups, such as those living in flood plains or in top floor flats in city centres, may be disproportionately exposed to climate change impacts that can affect their health. Others, for example those with pre-existing medical conditions or the elderly may in turn be disproportionately sensitive to climate change impacts. Finally, some groups, for example the isolated, those with limited mobility or immigrants with limited language skills and local knowledge may have particularly weak adaptive capacity. The nature of health outcomes a group or individual experiences is determined by the way in which their exposure, sensitivity and adaptive capacity construe their vulnerability. Vulnerability is compounded when multiple attributes associated with exposure, sensitivity and weak adaptive capacity align with each other.

In what follows, the evidence generated by the other technical papers will be reviewed and interpreted in light of additional literature so as to draw out the key observations regarding the potential implications of health and social inequalities for health outcomes of climate change. As this synthesising exercise is somewhat different from that one carried out in the other technical papers, the structure of this paper does not fully follow that of the other technical papers. In this synthesis paper,

each theme covered by the technical papers is discussed in turn, to highlight how health and social inequalities play into the observed and predicted outcomes. In the end, factors affecting the distribution of health outcomes due to climate change are considered and the potential measures to address the impacts of health and social inequalities are discussed and in the end conclusions are drawn.

2. Climate change and health and social inequalities

2.1 Emerging infections

Emerging infections or diseases are either newly appearing in a population or are rapidly increasing in incidence or expanding in geographic range, for reasons of which climate change is only one (Morens et al., 2004). Climate change can lead to emerging infections when it influences pathogens causing a disease: this is most likely when the pathogens spend part of their lives outside the host, making vector-borne diseases the most important category of infections influenced by climate change (Baylis 2014). Climate change can influence where and in what season a disease occurs and what its incidence is (ibid). For example, climate change is expected to influence the distribution of vector-borne diseases such as malaria, West Nile virus, Chikungunya fever, dengue, Leishmaniasis, Lyme's disease and tick-borne encephalitis (TBE).

Health and social inequalities can influence or be related to the outcomes of climate change related emerging infections in several ways. Firstly, factors influencing and patterns of vector ranges can give rise to North-South, urban-rural or other gradients in exposure to emerging diseases, depending on the specific disease in question. This differential exposure can align with income or/and age disparities, which can in turn lead to differences in sensitivities and adaptive capacities. For example, if older rural population is more exposed Lyme's disease and TBE, the people at greater risk of these diseases would also be more likely to have other pre-existing medical conditions and thus likely to experience more adverse health outcomes because of these diseases. In terms of adaptive capacity, the people in rural areas may have more limited access to health care services and in particular to medical expertise to do with emerging diseases.

2.2 Milder winters

Cold weather causes thousands of preventable excess deaths in the UK every year, proportionally more than in the colder Northern European countries. Many of these excess deaths happen as the result of cardio-vascular and respiratory illnesses, which are aggravated during cold spells (Hajat, 2014). Cold-related excess deaths are typically not short-term displacements of mortality, i.e. do not mainly occur in already frail individuals near the end of their lives unlike is the case with heat-related deaths (ibid). For these reasons, milder winters brought about by climate change are predicted to reduce winter mortality and mortality by 9% by 2020s and 26% by 2050s (Hajat et al, 2014; but cf. Staddon et al, 2014).

Health and social inequalities are closely linked to cold-related excess deaths. Factors that relate to elevated exposure to cold-related deaths include fuel poverty and poor housing (see Hajat, 2014). Older people are often suffering from both and can thus be more exposed than other groups. Those living in council housing may be less exposed than those living in their own property, as income limitations may make it difficult for older people to improve thermal comfort of their home. The older people are also more sensitive to cold because they cannot thermoregulate their bodies as well as other age groups (Hajat, 2014). Sensitivity to cold is further increased by pre-existing medical conditions such as cardiovascular or respiratory diseases, which are more prevalent in older age groups. Limited economic and informational resources in turn weaken the adaptive capacity of older people.

A warming climate may thus generate health benefits in terms of reduced excess mortality and morbidity due to exposure to cold, and it could particularly benefit those who are vulnerable. But while milder winters will have the potential to reduce cold-related deaths, they are not the only factor determining outcomes. Demographic change – particularly the aging population - will make a larger number of people sensitive to cold than today (see Oven et al, 2012). Increasing energy prices may in turn make it more difficult for a larger proportion of exposed and sensitive people to adapt by increasing indoor temperatures. There is also uncertainty regarding how higher annual and winter average temperatures will be achieved: they may very well

be consistent over the medium term with the co-existence of cold spells of the same or increased length and severity as in the past.

2.3. Flooding

Climate change is likely to increase the frequency and intensity of surface, riverine and coastal flooding in the UK (Defra, 2012). Every sixth property (5.2 million properties) is exposed to some flood risk in the UK (Environment Agency, 2009, p. 3). Figures for the number of people exposed to flooding in the UK range from 1.5 million to 5 million (see Lindley et al, 2011; Watkiss, 2009). Damage caused by flooding to buildings and contents of residential and non-residential properties amounts to about £1.3 billion per annum. In years such as 2007 when flooding is substantial the damage can double. The above figures exclude loss of income due to disturbance caused by flooding and additional expenses to make alternative arrangements for leisure, work or business. These losses can add 25-50% to losses related to buildings and contents (Lanz et al, 2012; Watkiss & Hunt, 2012).

Direct health impacts of flooding can include drowning, electrocution and other accidental deaths and injuries, and indirect impacts of flooding can occur due to the contamination and loss of water supply and loss of access to transport, electricity supply and communications connection (HPA, 2011; see also WHO, 2013). Those suffering economic losses and disturbance because of flooding can also develop mental health problems (Lindley et al 2011b). Paranjothy and co-authors (2011; see also HPA 2011) found that flooded participants in their study, which examined the after effects of 2007 summer floods in Gloucestershire and Yorkshire, were two to three times more likely than non-affected participants to report mental health problems (compare also with Mason et al, 2010; Whittle et al, 2010). Flooding has also capacity to undermine the health care provision because it can overwhelm the capacity of emergency services, cause power cuts or supply disruptions, and potentially flood health care facilities (see WHO 2013; Klinger et al, 2014).

The risk of flooding and thus its adverse health impacts are unevenly distributed in several ways. Those living in affordable housing and socio-economically disadvantaged households are over-represented in areas at risk from coastal

flooding while affluent households are more likely to be at risk from riverine flooding. Correspondingly, these groups are more exposed to flood risk and adverse health outcomes associated with flooding (Houston et al, 2011). Second, some groups are more sensitive to the impacts of flooding because of disabilities, chronic illness, having young children or being dependent on public transport. Finally, the capacity of some groups to adapt or recover can be lower because of low incomes or lack of insurance. Socio-economic background inequalities have substantial implications for people's ability to adapt to and recover from the impacts of flooding: losses to assets cannot be recovered and repeated exposure to flooding can deplete vulnerable households' assets and adversely affect their health so as to make them more vulnerable in the future (Whittle et al, 2010; Pringle et al, 2013). People's tenure status and type of dwelling may also influence the outcomes they experience.

2.4 Hotter summers and heat waves

Climate change is expected to increase temperature by 2-5°C by the end of the century in the UK, with an attendant increase in the frequency and intensity of heat waves. Research has established a link between increased mortality and increased temperature and heat waves. Heat related excess deaths occur primarily as a result of respiratory and cardiovascular illnesses (Arbuthnott, 2014). In England and Wales, mortality increases 2.1% for each 1°C increase in temperature above the 93rd percentile of average yearly temperature. The excess deaths caused simply by increased temperature can include substantial mortality displacement or "harvesting", while it plays a much smaller role in mortality due to heat waves. Heat related mortality has been projected to increase in the UK by 45 % by 2020s and by 167% by 2050s as the result of warmer weather and demographic changes and it will be the greatest in London, the Midlands and in the Southeast of England (see Hajat et al, 2014).

Older people are more at risk of heat-related death for several reasons. Their sensitivity is greater because of their weaker ability to thermoregulate (ibid.), and because they often suffer from other pre-existing medical conditions. They are also more likely to have prescribed medication, some of which is associated with increased risk for heat related death. Their adaptive capacity may be limited because

of isolation and lack of informational resources, or because of lack of mobility or autonomy. Lack of autonomy may for example prevent behavioural and other adaptations in residential or nursing homes. Alignment of several of these factors would accentuate vulnerability.

Exposure to heat is primarily linked to factors other than age unlike is the case with sensitivity and adaptive capacity. Exposure to heat is greater in the South and East of the country, and people living in urban settlements are more exposed than those living in rural areas due to the urban heat island (UHI) effect. Densely built neighbourhoods with limited amount of open space and green areas increase people's exposure to heat but the geometry of the buildings and how they are built also have a significant influence on the level of exposure (see Oikonomou et al, 2013). Top floor flats experience great thermal stress while ground floor flats do not. Ventilation has substantial influence on heat exposure – it may be constrained for reasons of physical building design or it may not be possible in some areas to ventilate because of crime and safety considerations. Many of these factors leading to greater exposure come together in deprived urban neighbourhoods.

2.5 Food safety

Campylobacter and salmonella are the key food safety related pathogens whose prevalence and impacts are likely to be affected by climate change. The cases of campylobacter have been increasing over time: in 2006 it led to 18 000 hospitalisations, 80 deaths and economic losses of £600 million per annum in England and Wales (Lake, 2014). However, the overall projections for campylobacter cases are uncertain because different drivers influence cases occurring via different (dietary vs. environmental) pathways differently. The cases of salmonella have in turn been decreasing: about 9000-10000 cases of salmonella have been reported to the Health Protection Agency in recent years and these have been estimated to have led to 8500 hospital admissions, 199 deaths and economic losses of £39 million per annum in England and Wales. Climate change has the potential to countervail the reduction in salmonella cases brought about by improved food hygiene over the past two decades.

In terms of exposure, campylobacter has been found to be more prevalent in rural areas and in areas with less social deprivation (Lake, 2014; Nichols et al, 2012). It is more common in infants than in adult and older age groups. Poultry is the most common dietary source of campylobacter so those whose diet is more importantly based on poultry may also be at greater risk. The geographic prevalence patterns of salmonella have not been studied in the UK. Salmonella is most commonly contracted from raw or undercooked eggs or poultry. Salmonella is most common in small children. Infants and the elderly are the worst affected in terms of adverse health outcomes by both campylobacter and salmonella due to their sensitivity. The elderly and households with small children are the two groups for whom food safety will be a particular problem because of the sensitivity of the infants and elderly and their situation can be exacerbated with low incomes, isolation and other factors that reduce their adaptive capacity.

2.6 Air Quality

Air quality, particularly the pollution of air by nitrogen dioxide (NO_2), ozone (O_3) and particulate matter (PM), has an adverse impact on health, which can be exacerbated by climate change. Exposure to these pollutants is associated with increased all-cause mortality and cardiovascular mortality and morbidity and exposure to ozone is also associated with increased respiratory mortality and morbidity (Doherty et al, 2014). The evidence from recent heat waves such as that of 2003 in the UK suggests that at least a third of excess mortality experienced during a heat wave may be attributable to exposure to elevated concentrations of O_3 and PM_{10} (ibid.). Several processes such as warmer weather, more frequent heat waves, changes in rainfall and altered volatile organic compound concentrations may contribute towards increased O_3 and PM concentrations in the future, although their or their pre-cursors' emissions as such may decrease over time (ibid.).

There is evidence that CO and NO2 concentrations are particularly high in cities near major transport corridors and that ethnic minorities are over-represented in these locations (Brainard et al, 2002). If PM concentrations share distribution patterns - which is plausible - then the increase in PM concentrations caused by climate change would increase the exposure of the same people to the adverse health

outcomes associated with PM. The situation with O3 is more complex as high NOX concentrations in urban areas inhibit the formation of O3. However, relatively high O3 concentrations can prevail in urban areas in the future changing climate if public policies will be bringing down NOX emissions (see Heal et al, 2013). In the absence of impacts of policy on NOX emissions, temperature increase due to climate change would increase mortality rates associated with O3 everywhere in the UK.

Social deprivation is a key factor alongside age for sensitivity to elevated O_3 and PM concentrations because it disposes people to have pre-existing cardiovascular illnesses. In 2008, the most deprived quintile in the UK experienced 50% higher mortality from cardiovascular disease than the least deprived quintile (Heart UK, 2013). Among women, the outcomes were even more unequal, women in routine jobs experiencing five times higher mortality from cardiovascular disease than women in managerial or professional jobs. These differences in cardiovascular disease risk and thus sensitivity to O_3 and PM pollution emerge as results of differences in the levels of deprivation, lifestyles, health literacy, access to health services, and environmental exposure (see Marmot Review, 2010). Social deprivation and ethnicity can also constrain adaptive capacity by limiting ability to relocate and to take other measures to avoid exposure or to reduce sensitivity.

2.7 Health and social systems

Climate change, particularly extreme weather events such as heat waves, cold spells, and flooding will affect health outcomes in the future because of their direct impacts on the built infrastructure of health care provision and on its social and institutional systems, and because of their indirect impacts on systems of health care through changes in the volume and structure of demand for health care (Curtis et al, 2014). As detailed above, heat waves and cold spells can put systems of health care under pressure because of the mortality and morbidity increase for cardiovascular and respiratory diseases and associated increases in the number of hospitalisations (ibid). Floods in turn result in increased accidents and emergency visits (for example, Thornes et al (2014) suggest that climatic extremes can increase ambulance call out rates by 25-35 %, which is comparable to increases related to major flu epidemics) and increased mental health problems and demand for services addressing them,

and influence the length of time that support addressing them is needed (ibid). Direct impacts of extreme weather events on health care systems include heat stress on patients in health and social care facilities and adverse health outcomes associated with this heat stress as outlined above, potential care and service disruptions because of power outages, delays in emergency responses and reduced access to health care because of the impacts of flooding and extreme weather on transport infrastructure and services, and reduced staffing and capacity for the same reasons in health care provision (Curtis et al, 2014).

Inpatients and those with urgent medical needs will be most exposed to impacts of extreme weather events on health care systems. Rural dwellers are likely to be more exposed to disturbance caused by cold spells and flooding, while urban residents may be exposed more to disturbance due to heat waves. Many of the exposed will be older people who are sensitive to care disruptions and reduced access to care because of pre-existing medical conditions such as cardio-vascular disease and respiratory diseases, which are directly aggravated by climate change impacts. Adaptive capacity is particularly restricted among those who are in residential care as they have little control over their circumstances, and among those who are isolated or have mobility restraints which may further complicate their access to care.

3. Climate change, social change and health and social inequalities

The previous section discussed how climate change can have differential health impacts on different groups of people, because of differences in their exposure, sensitivity or/and adaptive capacity. Young and old age (but particularly the latter), having pre-existing medical conditions and social deprivation are key attributes that make some people more vulnerable than others to health impacts of climate change, leaving them to experience more adverse climate change related health outcomes than others. However, there are also other attributes that can dispose people as more vulnerable to health impacts of climate change such as living in rural or urban locations, isolation, marginalisation and weak community cohesion, depending on the climate change impact in question.

The impact of climate change on health outcomes and their relationships with health and social inequalities was already discussed above. But climate change, aging population and potentially decreasing public spending on health and social care in per capita terms can combine to increase in the future health and social inequalities to do with climate variability and change. These health impacts will materialise when changes are going to take place in demography, public spending and public service delivery. For example, the number of people who are over 60 years old will increase by 50% by 2035 compared to 2010 (Office of National Statistics, 2012). The proportion of people who are over 75 will double in population by 2060 compared to 2010 (Appleby, 2013). This means that many more people will have co-morbidities or pre-existing medical conditions, which make them more vulnerable to health impacts of climate change. At the same time, the increasingly complex systems of health care depend on critical infrastructure for the supply of electricity and water and for communication – this critical infrastructure is exposed and sensitive to the impacts of climate change, which may undermine care (Klinger et al, 2014).

The aging of population increases the number and proportion of people who are vulnerable to health impacts of climate change at the same time when impacts of changing climate will increase. But ageing will also together with income increase, technological change and increase in the cost of health care provision drive up the spending on health and social care. Together these factors will create pressure to increase spending on health care from the current about 8% of GDP to 12-14% of GDP by 2040 (Appleby 2013: 18). This can be met either by simply increasing public spending, by substantial reallocation of public spending from other areas to health care, or by rationing or patient co-funding of health care provision. In this setting, health impacts of climate change will compete with other areas of health care demand for scarce resources. If the care is rationed or co-funded, those with greater needs and more limited means will suffer reduced access to health care, which will accentuate health and social inequalities to do with climate change.

4. Measures to mitigate the impacts of health and social inequalities

A range of strategies is available to address health impacts of climate change and the implications of health and social inequalities for them. These include for example new food safety and building regulations, incentivising refurbishment of old building stock and urban neighbourhoods (although Davies and Oreszczyn (2012) remind that targeted measures will need to be carefully assessed to avoid unintended consequences), enhanced emergency services and health care provision both in terms of operations and infrastructure, improved advance warning and preparedness systems, development and deployment of new diagnostic and therapeutic solutions and public health campaigns and health education, to name but just a few of the available generic solutions. None of these solutions is going to be sufficient on its own because compound inequalities underpin vulnerability (see Preston et al, 2014): a combination of measures will be needed to address the health impacts of climate change, and to mitigate the implications of health and social inequalities for them.

Individuals and organisations do have capacity for autonomous adaptation and one possible adaptation strategy is to depend on or emphasise it. This strategy of private preparedness and responsibility resonates with the arguments for people's responsibility for their own health and wellbeing. The strategy would emphasise public information campaigns and public health education to make people aware of the health risks associated with climate change, factors contributing to people's exposure and sensitivity, and alternatives for avoiding and mitigating adverse health outcomes, so that they can do their best in protecting themselves. Solutions such as advance warning systems would also support such strategies, signalling to people that they should be ready to deploy avoidance measures.

However, strategies relying on people's own initiative, action and behaviour change can be problematic from the viewpoint of health and social inequalities, and can increase rather than decrease them. Income and wealth inequalities often expose low-income groups to greater risks because of their residential and other choices, and their adaptive capacity can also be lower than high-income groups have. For example, income and wealth inequalities and different levels of trust and engagement translate to differential economic resources for undertaking avoidance

measures, which lead to different uptake of avoidance measures among different groups of people. Educational status, immigration status and age may also influence people's ability to translate health education into action plans, as well as to undertake avoidance measures in the first place. There is also evidence that people may not consider taking action to adapt to climate change to be their responsibility (see Bichard and Kazmierczak, 2012; Williams et al., 2012: 65-73).

Public preparedness measures on the other hand have good potential for alleviating health impacts of climate change linked to health and social inequalities. For example, early warnings targeting emergency services and public service delivery organisations may confer important benefits to vulnerable groups if they lead to improved preparedness and existence of joined-up contingency and emergency plans in different service delivery organisations (Pringle et al, 2013). In the area of flood risk management for example, Johnson et al (2007) suggest that emergency services are guided by different legislation and priorities than flood risk management, which make them better aligned to prioritising vulnerable groups (see also Brisley et al, 2012). Therefore, early warnings and public preparedness measures may make a particularly valuable contribution to socially just adaptation if they seek to improve the ability of authorities and public service organisations to deliver and target support and care across differently situated and affected groups.

5. Conclusions

Climate change will particularly exacerbate existing health problems in populations that are already most affected by climate-related diseases and reduce their resilience to future threats to their wellbeing. In addition, existing diseases will extend their ranges into areas that are presently unaffected and new conditions may also emerge in changing climate. In the UK, increased frequency and intensity of heat waves, extreme weather events and flooding and changing ranges of disease vectors and parasites are key climate change impacts that will impact on health outcomes. Climate change can also have an indirect impact on health for example via changing prices and availability of food.

Climate change will have differential health impacts on different groups of people, because of differences in their exposure, sensitivity or/and adaptive capacity. Age and social deprivation are the key attributes that make people more vulnerable than others, and they will lead to more adverse climate change related health outcomes among them. However, there are also other attributes such as living in rural or urban locations, isolation, marginalisation and social embeddedness in and cohesiveness of communities that can dispose people as more vulnerable. Climate change, aging population, decreasing public spending on health and social care and other regressive policy measures can combine to increase in the future health and social inequalities to do with climate variability and change.

Existing research on climate change impacts and health does already shed some light on the implications for health and social inequalities. However, less is known about the implications of response strategies to address health impacts of climate change, and more research would be needed in this area. Different strategies for avoiding or/and mitigating health impacts of climate change can have different implications for health and social inequalities. For example, health education and measures to improve public preparedness that explicitly take into account differential exposure, sensitivity and adaptive capacity of different groups of people may help to address health and social inequalities to do with climate change. Adaptation strategies based on individual preparedness and behaviour change in turn may aggravate health and social inequalities to do with climate change due to their selective uptake and because of the lack of engagement of some social groups, unless coupled with broad public information campaigns.

References

Adger W.N. 2006. Vulnerability. *Global Environmental Change* 16: 268-281.

Appleby J. 2013. Spending on health and social care over the next 50 years: Why think long term. London, UK: The King's Fund.

Arbuthnott K. 2014. Hotter Summers and Heatwaves and Health. *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Baylis M. 2014. Report card on emerging infections. *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Bichard, E. and Kazmierczak, A. (2012) Are homeowners willing to adapt to and mitigate the effects of climate change? Climatic Change 2012: 112: 633-654.

Brainard, J.S., et al., 2002. Modelling environmental equity: access to air quality in Birmingham, England. *Environment and Planning A* 34: 695–716.

Brisley R., Welstead J., Hindle R., Paavola J. (2012) *Just Adaptation Responses to Climate Change*. Joseph Rowntree Foundation http://www.jrf.org.uk/sites/files/jrf/climate-change-adaptation-full_0.pdf

Curtis S., A. Fair, J. Wistow, D. Val and K. Oven. 2014. Health care infrastructure in the United Kingdom: adaptation to the challenges of extreme weather events in the conditions of climate change. *LWEC Technical Paper for Health Climate Change Impact Report Card*.

Davies M., Oreszcsyn T. (2012) The unintended consequences of decarbonising the built environment: A UK case study. *Energy and Buildings* 46: 80-85.

Department of Environment, Food and Rural Affrairs (DEFRA). 2012. The UK Climate Change Risk Assessment 2012: Evidence Report. Available online at http://randd.defra.gov.uk/Document.aspx?Document=10067_CCRAEvidenceReport16July2012.pdf

Doherty R., M. Heal and F. O'Connor. 2014. Climate change impacts on human health through its effects on air quality. *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Environment Agency (2009) Flooding in England: A National Assessment of Flood Risk. Bristol: Environment Agency. Available online at http://publications.environment-agency.gov.uk/PDF/GEHO0609BQDS-E-E.pdf

Hajat S. 2014. Health effects of milder winters. *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Hajat S, S Vardoulakis, C Heaviside and B Eggen. 2014. Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s. *Journal of Epidemiology and Community Health*.

Heal M.R, Heaviside C., Doherty R.M., Vieno M., Stevenson D.S., Vardoulakis S. (2013) Health burdens of surface ozone in the UK for a range of future scenarios. Environment International 61: 36–44.

Health Protection Agency (HPA). 2011. *The effects of flooding on mental health*. London, available online at

Heart UK. 2010. Bridging the gaps: Tackling inequalities in cardiovascular disease

Houston, D., Werritty, A., Bassett, D., Geddes, A., Hoolachan, A. and McMillan, M. (2011) Pluvial (rain-related) flooding in urban areas: the invisible hazard. York: Joseph Rowntree Foundation. Available online at http://www.jrf.org.uk/sites/files/jrf/urban-flood-risk-full.pdf

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fifth Assessment Report. http://www.ipcc-wg2.gov/AR5/

Ipsos MORI Research Institute, (2013) *PREPARE - Climate risk acceptability: Findings from a series of deliberative workshops and online survey*, Part of the PREPARE Programme of research on preparedness, adaptation and risk, Final Report for project ERG1211 by Ricardo-AEA for Defra. Report reference Ricardo-AEA/R/ED58163/PREPARE R3/Issue 1.0.

Johnson, C., Penning-Rowsell, E., and Parker D. (2007) Natural and imposed injustices: the challenges in implementing 'fair' flood risk management policy in England. *Geographical Journal* 173: 374–390.

Klinenberg, E. (2002) *Heatwave: A Social Autopsy of Disaster in Chicago*. Chicago, IL: University of Chicago Press

Klinger C, Landeg O, Murray V. (2014) Power Outages, Extreme Events and Health: a Systematic Review of the Literature from 2011-2012. *PLOS Currents Disasters*. 2014 Jan 2. Edition 1.

Lake, I. 2014. Food borne disease and climate change. *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Lantz, V., Trenholm, R., Wilson, J. and Richards, W. (2012) Assessing market and non-market costs of freshwater flooding due to climate change in the community of Fredericton, Eastern Canada. Climatic Change 110: 347–372.

Lindley, S. O'Neill, J., Kandeh, J., Lawson, N., Christian, R. and O'Neill, M. (2011) Climate Change,Justice and Vulnerability. York: Joseph Rowntree Foundation. Available online at http://www.jrf.org.uk/sites/files/jrf/climate-change-social-vulnerability-full.pdf

The Marmot Review. 2010. *Fair Society, Healthy Lives*.

Mason, V., H. Andrews and D. Upton (2010) The psychological impact of exposure to floods. *Psychology Health & Medicine,* 15**:** 61-73.

Morens DM, Folkers GK and Fauci AS. (2004) The challenge of emerging and re-emerging infectious diseases. *Nature* 430: 242-249.

Morris, G.P., S. Reis, S. Beck, LE Fleming, WN Adger, TG Benton and MH Depledge. 2014. Climate change and health in the UK: scoping and communicating the distal dimension. . *LWEC Technical Paper for Health Climate Change Impact Report Card.*

Nichols G.L., Richardson J.F., Sheppard S.K., Lane C., Sarran C. (2012). Campylobacter epidemiology: A descriptive study reviewing 1 million cases in England and Wales between 1989 and 2011. BMJ Open; 2.

Office for National Statistics (2012). 2010-based National Population Projections Reference Volume: Chapter 2: Results. Series PP2. London: Office for National Statistics. Available at: www.ons.gov.uk/ons/dcp171776_253934.pdf

Oikonomou E., Davies M., Mavrogianni A., Biddulph P., Wilkinson P., Kolokotroni M. (2012) Modelling the relative importance of the urban heat island and the thermal quality of dwellings for overheating in London. *Building and Environment* 57: 223-238.

Paranjothy S, Gallacher J, Amlot R, Rubin G J, Page L, Baxter T, and others. 2011. Psychosocial impact of the summer 2007 flood in England. *BMC Public Health* 11: 145.

Pitt M. 2007. *The Pitt Review: Learning Lessons from the 2007 Floods - Full Report*. UK Government National Archives.

Preston I., Banks N., Hargreaves K., Kazmierczak A., Lucas K., Mayne R., Downing C. , Street R. (2014) *Climate Change and Social Justice: An Evidence Review*. Joseph Rowntree Foundation. Available online at http://www.cse.org.uk/downloads/file/climate%20change%20and%20social%20justice%20evidence%20review.pdf

Pringle P., Paavola J., Dale N., Sibille R., Kent N., Le Cornu E. (2013) *PREPARE: Understanding equity and distributional impacts of climate risks and adaptation options*. Final Report for project ERG1211 by Ricardo-AEA for Defra. Available at http://randd.defra.gov.uk/-Document.aspx?Document=11257_PREPARECA0513Socialvulnerability-Finalreport.pdf

Staddon P. L. Montgomery H.E., Depledge, M.H. (2014) Climate warming will not decrease winter mortality Nature Climate Change 4: 190-194

Thornes J.E., Fisher P.A. Rayment-Bishop T. (2014) Ambulance call-outs and response times in Birmingham and the impact of extreme weather and climate change. *Emergency Medicine Journal* 31(3):220-228. doi:10.1136/emermed-2012-201817

Watkiss P., Hunt A. (2012) Scoping Study: Reviewing the Coverage of Economic Impacts in the CCRA. Report to the Committee on Climate Change / Adaptation Sub-Committee.

Whittle R., Medd W., Deeming H., Kashefi E., Mort M., Twigger Ross C., Walker G., Watson N. (2010) *After the Rain – learning the lessons from flood recovery in Hull*, final project report for *Flood, Vulnerability and Urban Resilience: a real-time study of local recovery following the floods of June 2007 in Hull* project, Lancaster University, Lancaster UK.

WHO (2013) Floods in the WHO European Region: health effects and their prevention (http://www.euro.who.int/__data/assets/pdf_file/0020/189020/e96853.pdf).

Williams K., Gupta R., Smith I., Joynt J., Hopkins D., Bramley G., Payne C., Gregg M., Hambleton R., Bates-Brkljac N., Dunse N. and Musslewhite C. (2012) *Suburban Neighbourhood Adaptation for a Changing Climate (SNACC) Final Report*. Available online athttp://snacc.files.wordpress.com/2012/10/snacc_report.pdf

.