Climate Change and its Health Implications
A summary report for environmental health practitioners on the health implications of climate change

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Introduction 05

1.0 Weather and climate change: background 06
   1.1 What is climate change? 06
   1.2 Air pollution and climate change 06
   1.3 Natural climate variability 08

2.0 How future climate change is predicted: climate change scenarios 09
   2.2 The importance of greenhouse gases 09
   2.3 ‘Warm years’ and climate change scenarios 12
   2.4 Other scenarios used to project the impact of climate change 12
   2.5 The uncertainties in climate change scenarios 12
   2.6 Changes for which there is ‘high confidence’ 12

3.0 The range of the change: summary of main indicators and projected regional changes 14
   3.1 Temperature 14
   3.2 Precipitation (rainfall) and snow 18
   3.3 Floods 25
   3.4 Storminess 26
   3.5 Sea and ground water level 26
   3.6 Other climate change indicators 27

4.0 Health impacts: overview 30
   4.1 Introduction 30
   4.2 Global environmental health 30
   4.3 Health impact assessments for climate change 31
   4.4 Types of health effects 32
   4.5 Predictive modelling of climate change effects on health 32
   4.6 The range of climate related health problems 33
   4.7 Ultraviolet radiation and the depleted ozone layer 33

5.0 Temperature effects on health 36
   5.1 Health impacts of heatwaves 36
   5.2 Evidence of climate change effects on infection incidence and distribution 37
   5.2.1 Food poisoning 37
   5.2.2 Vector borne disease: malaria, tick borne encephalitis, Lyme disease 38
   5.3 Water-related disease and climate change 40

6.0 Health impact from floods 42
   6.2 The range of health risk from floods 42
   6.3 Infections and epidemics following floods 44
   6.4 Chemical pollution and floods 44
   6.5 Mental health problems associated with floods 45

7.0 Health impact from windstorms and air quality changes 46
   7.2 Health effects of air pollution with a changing climate 48

8.0 Mitigating climate change 49
   8.2 European Commission position on climate change 49
   8.3 The Climate Change Bill 50
   8.4 Progress with the Kyoto Protocol 51
   8.5 Economic impact of mitigation 51
   8.6 Energy supply industries (ESIs) 52
   8.7 Business: manufacturing and commercial sectors 52
   8.8 Transport 53
   8.9 Domestic sector 53
   8.10 Agriculture, forestry and land use 55
   8.11 Public sector 55
   8.12 Secondary impacts of mitigation: balancing beneficial and potentially harmful effects 55
   8.13 Population and global warming 55

continued on next page >
9.0  Adapting to climate change 58
9.1  Adapting buildings and infrastructure to climate change 58
9.2  Long-term and emergency planning for floods and related storms 58
9.3  Health and hygiene advice after floods 59
9.4  Adapting to windstorms 61
9.5  Water treatment and management/sanitation 63
9.6  Adapting to heatwaves 63
9.7  Protecting vulnerable groups 64
9.8  Reducing the impact of climate change on infectious disease 65
9.9  Adapting our surveillance systems 66
9.10 Advantages (and limitations) of adaptation measures 67

10.0 Summary and conclusion 69
10.1 Assessment at a time of uncertainty 69
10.2 Summary of climate change and its health effects 69
10.3 Early actions needed to protect environmental health 70

References and sources of information 72
Appendix List of tables, boxes and figures 82
Introduction

“Warming of the climate change system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” IPCC Report, 2007

This pack presents information and strategies on climate change for those working in environmental health in the United Kingdom, at a time when there is increasing political interest in reducing the possible future effects, such as the Climate Change Bill, a revised UK Energy policy (July 2006), the commitment by the European Union to reduce carbon dioxide emissions – and a forest of new or forthcoming regulations.

The evidence for climate change and the contribution to this change from human activities is now substantial, yet there is a continuing debate about what to do about it. The timescales are vast and well outside normal planning preparations. Also, predicting the pattern of change in the future is notoriously inexact. Currently, a few scientists are warning that some climate change effects, such as depletion of the Greenland ice sheet, are occurring more rapidly than expected, but others, such as the Intergovernmental Panel on Climate Change (IPCC) are more cautious. The only agreement is that action is needed today to prevent dangerous effects of climate change in the future.

Extreme weather events – such as the wettest UK summer in recorded meteorological history in 2007 – help to focus on where we are not prepared for the effects of climate change. We have been told that carbon dioxide emissions need to be more strictly managed now, to avert more dangerous climate change by the middle of this century. Adaptation measures, which could bring more immediate benefit, are now receiving more attention, for example regarding flood defences/preparation and planning for heatwaves and windstorms. It is likely that over the next decade there will be increased community pressure to plan for the effects of climate change.

The rise in global temperature is the best documented and this alone will require different approaches and strategies to minimise impact on health. Other changes, such as variation in rainfall, intensity or frequency of storms, floods and droughts, require longer time series for accurate prediction of trends. This long timescale makes planning difficult and complacency an easy strategy; but even for climate change cynics, the high place of climate change on the political agenda provides an opportunity to better prepare for disasters that this island’s weather may bring. Overall, the questions this pack aims to answer are simply: what are the main health impacts we can expect from current knowledge on climate change and what should environmental health professionals be planning for?
What is climate change?

Climate change is often used synonymously with the term ‘global warming’, referring to the confirmed increase in the Earth’s mean surface temperature over the last 200 years, although it involves several other variables (Box 1.1). An important point, and one that causes endless confusion in debates about climate, is that change not attributed to global warming is not classified as ‘climate change’, but rather as ‘natural climate variation’: a possible example is the recent increase in storms, which are not at present thought to be related to human-induced global warming. The relationship between human activities and global warming is now beyond scientific doubt – although there are still several vocal cynics and the Royal Society in London produced a guide to ‘Climate Change Controversies’ in 2007 that includes question and answer points for climate change cynics (www.royalsoc.ac.uk).

The current record for the warmest year in the last thousand years is 1998. The Central England Temperature series (CET) is the longest instrumental temperature record in the world, dating back to 1759 with daily time series available from 1772 and daily maximum and minimum temperatures from 1878. The mean annual CET is now over 2°C higher than in the coldest period of the late 17th century (the ‘Little Ice Age’). Half of this increase occurred in the last 40 years, accompanied by a rise in the number of hot days. During the last 250 years, total summer rainfall in England and Wales has decreased by about 50mm, while autumn and winter rainfall has increased by about the same amount. And yet 2007 saw the wettest June on record, demonstrating that climate change can only be measured over long time periods, centuries rather than decades: this is why the confirmation of our altering climate has occurred only recently. The conventional time period for describing climate, established by the World Meteorological Organisation early in the 20th century, is 30 years.

Box 1.1 Climate change – definition

Climate change may be defined as the long-term alteration in the average weather conditions for a particular location. It becomes apparent as a change in annual, seasonal or monthly means of climate variables such as temperature, rainfall, sea level and extreme weather events such as heatwaves and floods over long time periods. Climate change also refers to the significant increase in the Earth’s surface temperature (global warming) monitored over the last 200 years and attributed mainly to human activity; and associated changes in climate variability and distribution at the global, regional or local scale.

The alteration attributable to human activities, such as the rising concentration of greenhouse gases (e.g. carbon dioxide, water vapour, methane, nitrous oxide) in the atmosphere is considered to be a key contributor to climate change. Carbon dioxide forms only a small part of the atmosphere, but has a disproportionate effect through its property of strongly absorbing heat. The level of CO₂ makes up 380ppm (parts per million) now, in contrast to 280ppm in the pre-industrialisation age: gases found trapped in cores of polar ice show 35% less CO₂ than current atmospheric levels (Royal Society, 2007).

1.2 Air pollution and climate change

Climate model experiments have shown that natural ‘internal variability’ in global climate cannot explain the observed surface warming and stratospheric cooling. The models show closer agreement with observed climate patterns when they include the radiative forcing due to rising concentrations of greenhouse gases (principally CO₂, methane) and shifting
distributions of sulphate aerosols. In general, levels of pollution in the UK are falling, for example with decreases in particles, nitrogen dioxide and sulphur dioxide – and these decreases are expected to continue during this century. However, tropospheric ozone (O₃) levels are increasing, in association with depletion of stratospheric ozone due to accumulation of greenhouse gases and chemical emissions: at this stratum of the atmosphere, O₃ is a major pollutant, produced by photochemical reactions of precursor gases such as carbon monoxide, nitrogen dioxide, methane and volatile hydrocarbons emitted from combustion engines and natural sources. In 2001, human activity was estimated to emit several billion tonnes of carbon into the atmosphere each year – and since then, reduction in emissions by a few countries has been countered by increased emissions from parts of the world with rapid industrialisation.

CO₂ and other greenhouse gases (GHGs) accumulate in the atmosphere because of the differences between annual emissions and the capacity of Earth’s ‘sinks’ whereby emissions are removed. Forest growth and the oceans absorb one third of human-induced carbon emissions, leaving the remainder to accumulate in the atmosphere. Other sinks for GHGs include photolytic destruction in the stratosphere; aerosols are to some extent washed out by precipitation. Fossil fuel combustion and cement production supply a large proportion of the carbon emissions, with a further contribution from changes in land-use in the tropics, especially deforestation. The current methane (CH₄) concentration is more than double its pre-industrial level, the main sources being rice paddies, animal husbandry, biomass burning and landfills. CH₄ is removed relatively quickly from the atmosphere via oxidation by hydroxyl radicals, persisting in the atmosphere for 12-17 years. Unfortunately, the oxidation produces water vapour, which is also a greenhouse gas. Another important greenhouse gas, nitrous oxide (N₂O) is produced by biomass burning, industrial processes and use of nitrogen fertilizers in agriculture. Natural sources contribute about twice as much N₂O. It has a relatively long lifetime in the troposphere (120 years) and contributes to stratospheric ozone depletion. Halocarbons (such as chlorofluorocarbons (CFCs) and halons, e.g. bromine) are produced by propellants, refrigerants, foam-blowing agents, solvents and fire retardants. Most persist for more than 100 years in the atmosphere, CFC atmospheric concentrations increased in recent decades but they have begun to decline due to controls introduced under the Montreal Protocol (1987) and its later amendments: they are potent GHGs, hence the concern, for example, about disposal of refrigerators.

The warming effect of the greenhouse gases is offset only very slightly by the cooling effects of ozone and sulphur dioxide. The cooling effect of sulphate aerosols is very small and there are wide confidence limits on its potential effects. Sulphate particles in the atmosphere partly derive from the sulphur-containing gases emitted by volcanoes. The burning of fossil fuels also produces some of the sulphates in the atmosphere. Cooling effects are reduced by the continuing ozone depletion. While carbon-based emissions are the principal driver of human-mediated global warming and the main focus for mitigation measures, the production of other GHGs through biomass burning/landfill/industrial processes must also be considered.
1.3 Natural climate variability

Natural causes of climate variation include volcanic eruptions and solar variability. An example of a short-term and naturally occurring climate variation is the El Niño Southern Oscillation (ENSO), a cyclic atmospheric and oceanic phenomenon affecting the eastern tropical Pacific Ocean. The periodic arrival of ENSO is not related to climate change, but it has been suggested that the changing climate trends worsened the effects of the ENSO during 1997 and 1998, for example torrential storms (WHO, 1999) and interannual variability in the incidence of malaria, dengue and other mosquito-borne diseases (Kovats et al, 1999) (Box 1.2). Other natural effects include the influence of thermohaline circulation (THC) in ocean currents, such as the Gulf Stream that warms the UK and North Western Europe. It has been suggested that climate change could disrupt the THC, slowing it down or moving it south, although this is currently believed to be very unlikely.

Box 1.2 Climate change and the El Niño Southern Oscillation

Warm episodes of the ENSO phenomenon (which consistently affects regional variations of precipitation and temperature over much of the tropics, sub-tropics and some mid-latitude areas) have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years. IPCC, 2001

European climate will also vary naturally over future decades, with or without substantial human influence: however, natural causes of climate change account for only a sixth of the 0.4°C rise in mean temperature since 1975 (IPPC, 2001). Climate change is also discussed in the context of other environmental changes attributed to human activity, such as stratospheric ozone depletion, loss of biodiversity, and decline in ocean fisheries, land degradation, disturbances of marine ecosystems and depletion of freshwater supplies. At the international political level the degree to which human activities can be changed, to slow the rate of climate change, is still a matter of active debate and negotiation. Industrial economies rely heavily on carbon-intensive energy; in less than two hundred years, we have increased the levels of carbon dioxide and other greenhouse gases by about 50% compared with pre-industrial levels (Hulme & Jenkins, 1998). Climate trends during the next fifty or so years are unlikely to be affected by any reduction in greenhouse gases but various climate scenarios and models have been proposed to estimate the changes over a range of time periods, based on how well we adapt to climate change, as well as to how effectively the human causes of global environmental changes can be controlled.
2.0 How future climate change is predicted: climate change scenarios

Climate change scenarios are computer generated models of how the world’s climate may develop.

2.1 Climate change scenarios are computer generated models of how the world’s climate may develop. Mathematical modelling has been used in the United Kingdom at the Hadley Centre since 1987 because of the various uncertainties in predicting climate change precisely. The models are known as Global Climate Models (GCMs) or General Circulation Models (also GCMs). The models perform climate change experiments based on factors such as the ocean system (e.g. currents, ice, sea level and heat transport), cloud type, vegetation and greenhouse gas emissions, as well as weather measurements. UKCIP08 scenarios are expected to be published in Spring 2009 www.ukcip.org.uk

2.2 The importance of greenhouse gases

Greenhouse gas level variations are the focus of the GCM experiments: a forcing of 1% per year increase in the equivalent CO$_2$ atmospheric concentration was used in early models, but four different forcing increases are now used. The models have evolved to allow scenarios based on three-dimensional representations of the ocean and terrestrial biosphere. The most recent climate change experiments have investigated the response of the climate system to different scenarios of radiative forcing (0.4%-1.2% increases in equivalent CO$_2$). Models can now fix results to calendar years (rather than the previous 10 year periods such as 2020s/2050s/2080s). Although spatial resolution has been raised from to 50km within the UK in recent models, the scale is still broader than most impact assessments for local areas.

The aim of a scenario is not to predict the future, but to set out a broad range of possibilities to inform vulnerability and adaptation assessments. Scenarios do not include changes in natural forcing factors, such as volcanoes, because of the high uncertainty of effects. Four models have been used to predict the patterns likely to occur in the UK by the UK Climate Impacts Programme (UKCIP), known as ‘low’, ‘medium-low’, ‘medium-high’ and ‘high’ – these were updated in 2002 to take account of generally higher carbon dioxide emissions and lower sulphur dioxide emissions, as well as changed representation of sea water expansion/glacier melting. The ‘medium-high’ scenario is the most commonly cited, as most likely to match the projected greenhouse emissions that will be experienced (Box 2.1). The scenarios represent a convenient assumption of human-related emissions rather than as ‘best guess’ outcomes.

Box 2.1 The medium-high scenario for the UK

The medium-high scenario for climate change (Hadley Centre, UK) is based on estimated increase in greenhouse gas concentrations. The UKCIP02 scenario, based on higher greenhouse gas emissions, predicts a 1-1.5°C increase in UK summer temperature compared with the 1961-90 mean, and 0.5-1°C increase in winter temperatures. Summers are predicted to be drier than estimated in the 1998 model, with the largest changes occurring in SE England.

The uncertainty in temperature estimates for these scenarios is plus or minus 5% of projected change for a particular area. UKCIP02 scenarios use time slices of 30 year periods as representative of future time, so that ‘2020s’ in Figures 2.2-2.4 represent the 30 years from 2011-2040. For comparison with the updated scenarios, Figure 2.1 shows the change in mean annual temperature between 1961-90 and 2070-99, as projected in UKCIP98. In the updated UKCIP02 scenario for medium-high emissions (Figure 2.2), it becomes more evident that the most dramatic change in temperature is projected for after the 2020 ‘timeslice’, although southern/SE England is likely to be noticeably warmer by the 2020s. Similarly precipitation changes will be greater after this decade (Figure 2.3), except for the southern half of...
Britain and Ireland, which shows significantly reduced rainfall by 2011-2040. The diurnal, (as opposed to mean), temperature change is shown in Figure 2.4 for the 2020s timeslice: most of the UK and Ireland show temperature increases, particularly in the summer. These time-slice projections show change based on the modelled 1961-1990 baseline for each emissions scenario.

Figure 2.1 Changes in mean annual temperature for low, medium-low, medium-high and high climate change scenarios (UKCIP98)

Source: UKCIP98 Climate Change Scenarios
(funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

Figure 2.2 Mean temperature changes for 2020s, 2050s and 2080s (UKCIP02)

Source: UKCIP02 Climate Change Scenarios
(funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
Mean precipitation change for 2020s, 2050s and 2080s (UKCIP02)

Diurnal* temperature change for low, medium-low, medium-high and high emissions in the 2020s (UKCIP02)

*The diurnal temperature range = daytime minus night-time temperature. Diurnal temperature change is closely related to changes in cloudiness, with clear days generally having a higher diurnal range of temperature.
While the climate change scenarios are essential for planning and mitigation, the inherent uncertainties must be acknowledged

2.3 ‘Warm years’ and climate change scenarios

Another way of using the climate scenarios is to estimate the number of warm years (annual mean temperature +1.6ºC above 1961-90 mean) we can expect in future decades: this varies from once per decade between 2010 and 2040 (2020s) (low scenario) to nearly seven times a decade (high scenario). With the medium-high scenario, 59% of the years in the 2020s will be warmer than the 1961-90 mean temperatures. By the 2080s, the probability of winter nights below freezing will drop from 0.2 to 0.07 in South East England and from 0.28 to 0.11 in Scotland (Hulme et al, 2001). Also in the medium-high scenario, summer precipitation in Southern England is estimated to fall below 50% of current average in 7% of the 2020s, while two-year precipitation totals will fall to below 90% of average. During winter, precipitation intensity is estimated to increase by up to 150% by the 2080s, according to the Hadley Centre Regional Climate Model (Hulme et al, 2001). While it is difficult to make precise estimates for earlier decades, there appears to be a strong likelihood of riverine flooding in various UK catchments, a prediction that is being examined in more detail after the widespread floods of 2007.

2.4 Other scenarios used to project the impact of climate change

Socio-economic scenarios attempt to show how the world or a region may develop depending on factors such as globalisation and conservation initiatives. Spatial analogue climates compare climate in a target area with a distant location that may represent how the climate will develop in the target area. These types of scenarios are described in more detail in the glossary.

2.5 The uncertainties in climate change scenarios

While the climate change scenarios are essential for planning and mitigation, the inherent uncertainties must be acknowledged. Factors that cannot be judged with precision include:

1. unknown level of future greenhouse gas emissions
2. natural climate variability
3. different response between different global climate models
4. poorly resolved regional and local climate changes (large scale of models)
5. the possibility of abrupt, non-linear change in the climate system (for example, disintegration of the west Antarctic ice sheet would rapidly raise sea levels; or a collapse of the thermohaline current in the north Atlantic could cool NW Europe by around 3ºC; conversely more rapid climate warming could result from the response of the natural carbon cycle to human-induced climate change)
6. spatial scale at higher resolution than 50km

2.6 Changes for which there is ‘high confidence’

The UKCIP02 report adopted a scale of relative confidence – high, medium and low (for example, there is low confidence in predictions of windspeed). Directions of change categorised as ‘high confidence’ include average temperature, winter rainfall and summer soil moisture (Table 2.1 and Figure 2.5). It should be emphasised that these are relative rather than absolute judgements, based on the understanding of the climate change researchers on the physical reasoning involved, consistency between models and statistical significance of the results.
High confidence statements re: direction of climate change (UKCIP02)

*Heating ‘degree days’ is an index used to calculate how much energy is needed to heat a building to a given temperature; the cooling degree day index calculates energy needed to cool buildings.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average temperature/summer temperature</td>
<td>Increase – higher in SE than in NW England</td>
</tr>
<tr>
<td>Temperature extremes</td>
<td>Increase in frequency of high extremes, decrease in low extremes</td>
</tr>
<tr>
<td>Sea-surface temperature</td>
<td>Increase</td>
</tr>
<tr>
<td>Thermal growing season</td>
<td>Longer</td>
</tr>
<tr>
<td>Heating and cooling ‘degree days’*</td>
<td>Heating days reduce, cooling days increase</td>
</tr>
<tr>
<td>Winter precipitation</td>
<td>Increase + increase in intensity</td>
</tr>
<tr>
<td>Snowfall</td>
<td>Decrease</td>
</tr>
<tr>
<td>Summer soil moisture</td>
<td>Decrease</td>
</tr>
<tr>
<td>Specific humidity</td>
<td>Increase</td>
</tr>
<tr>
<td>Sea level</td>
<td>Rise + increase in frequency of extreme levels</td>
</tr>
</tbody>
</table>

Figure 2.5 Summer soil moisture projections for 2050s (UKCIP02)

Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
3.0 The range of the change: summary of main indicators and projected regional changes

We face the largest world temperature change since the end of the ice age

3.1 Temperature

The warming to date has been greater over land than sea and at night. Dry hot spells (with average temperature above 25°C) are due to increase, particularly in S and W England, with drought periods extending by 4-6 days – although longer droughts cannot be excluded because of uncertainty in the climate models. Cold spells (prolonged periods with daily minimum temperature below freezing) will shorten throughout the UK, the largest impact being in Scotland. Previous suggestions that the North Atlantic thermohaline circulation system could shut down (leading to colder winters) are now considered extremely unlikely by climate researchers. Scenarios by region are shown in Figure 3.2. These use the high resolution (~50km) regional model of the European atmosphere (HadRM3). Only the periods 1961-1990 and 2071-2100 could be simulated by the regional model: the latter period is termed the ‘2080s’ for convenience. Scenarios for intervening time periods (2020s and 2050s) were derived by a process called pattern-scaling to study the effect of whether emissions will be at the

Figure 3.1 Global air temperature in UK time series (Climatic Research Unit and UK Met. Office)
lower or higher end of estimates. 2020s covers the 30 year time period from 2011-2040; 2050s covers 2041-2071.

In general, the regional scenarios show little significant change by the 2020s: where the maps are coloured green, there is no change in temperature in the scenario. The UKCIP02 report gives a detailed explanation of how the scenarios were derived.

Figure 3.2 (a-l) Changes in annual average daily temperature by region
Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
North East England

North West

Northern Ireland

Scotland
South East

South West

Wales

West Midlands

Low Emissions scenario

High Emissions scenario

change in deg C

1
2
3
4
5
6
0

2020s 2050s 2080s

Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change
In England and Wales precipitation records are available from 1766 and are routinely updated monthly by the Meteorological Office.

3.2 Precipitation (rainfall) and snow

While the rise in temperature is documented worldwide, many countries do not have long-term continuous records of other changes such as precipitation and drought. In England and Wales precipitation records are available from 1766 and are routinely updated monthly by the Meteorological Office (Figures 3.3-3.4). Thirty-year time scales have demonstrated variations of ±10% annually or over ±20% on a seasonal basis. Warm air can hold more moisture than cold air, making more precipitation likely, but with an uneven distribution. An increase in total rainfall can occur because of more wet days, but also if it rains harder on rainy days, or a combination of the two. Definitions based on what is unusual for local conditions may be more useful than fixed definitions of ‘heavy precipitation’ (Osborn, 2000). On this basis, heavy precipitation has increased on average over the UK since 1961 (Figure 3.5). The UKCIP02 scenarios indicate the possibility of drier summers than reported in UKCIP98, particularly for Scotland, where a smaller autumn/winter rainfall increase is predicted. Regional alterations in summer rainfall according to low, medium and high Climate Change Scenarios are shown in Figure 3.6 and those for winter rainfall in Figure 3.7.
Number of days each winter following 5 days of ‘very wet’ weather and hence flooding risk. Red = below average; blue = above average. Black smoothing line highlights variation over decades.

Contribution to each winter’s total precipitation made from ‘heavy’ precipitation days. Red = below average; blue = above average. Black smoothing line highlights variation over decades.

Percentage change in summer precipitation
Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

Figure 3.4

Figure 3.5

Source: Climate Research Unit (CRU), Osborn 2000/2007
(www.cru.uea.ac.uk/cru/info/ukrainfall)

(a) East Midlands

(b) East of England

Source: Climate Research Unit (CRU), Osborn 2000/2007
(www.cru.uea.ac.uk/cru/info/ukrainfall)
20 Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change
(g) Scotland

(i) South West

(h) South East

(j) Wales

Low Emissions scenario

High Emissions scenario

per cent change

2020s 2050s 2080s

Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change
Figure 3.7 (a-l) Percentage change by region in winter precipitation
Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

(k) West Midlands

(l) Yorkshire and Humber

(a) East Midlands

(b) East of England
Low Emissions scenario

High Emissions scenario

2020s 2050s 2080s per cent change

-30 -15 0 15 30 45

-60 -45 -30 -15 0 15 30 45

Low Emissions scenario

High Emissions scenario

2020s 2050s 2080s per cent change

-30 -15 0 15 30 45

-60 -45 -30 -15 0 15 30 45

London

North West

North East

Northern Ireland
Low Emissions scenario

High Emissions scenario

2020s 2050s 2080s

per cent change

-60 -45 -30 -15 0 15 30 45

Scotland

South East

South West

Wales
The prime minister said the flooding had been “an emergency that no-one could have predicted”
BBC website report, July 2007

With the current predicted pattern of precipitation, some countries will get wetter, including many parts of the UK, while others become drier, with variation across regions and with seasons. For example data suggest a Mediterranean type of rainfall pattern for parts of the UK. In northern and temperate countries, rainfall has increased during the winter, with a shift towards higher intensity events such as heavy rains and snowstorms; there is a trend towards less intense precipitation during the summer. In tropical and semi-tropical climates, the trend is for decreased precipitation and prolonged droughts, with wide variation.

There will be less snow throughout the UK, with the smallest reductions understandably in the Scottish Highlands – although even in this region, the decrease by 2080s may be 60% relative to present day totals (UKCIP02). Snowless winters are likely in many other areas of the UK.

3.3 Floods

The prime minister said the flooding had been “an emergency that no-one could have predicted”. BBC website report, July 2007

It would no doubt be unfair to say that floods in the UK always seem to take the government by surprise: one problem in assessing the flood risk associated with climate change is that to date, the evidence of an upward trend in flooding remains inconclusive (Ahern et al, 2005). During the last decade, there appears to have been an accumulation of high-magnitude floods in Europe, but this is still too small a number to confirm statistically that there is a genuine trend, or whether the cause is climate change. It has also been suggested that reporting and categorising flood events has improved, leading to more comprehensive data sets and hence apparent increased trends. Environmental changes, such as land cover and urbanisation, affect water absorption and runoff rates; and these are two of the many drivers of flood dynamics, so at the current time neither the frequency, nor the timing, of floods can be predicted with high confidence.
Meanwhile we should probably be better prepared for flooding as an emergency in the UK, as occurred in the autumn of 2000 with the worst flooding in York for 400 years and in Derbyshire for 30 years; and in summer 2007 with the heaviest precipitation on record and the largest flood disaster experienced for over 50 years. The 2007 floods in the north east, Midlands and west of England provided a further demonstration of the wide ranging disruption and health implications of flooding. In general, the climate change scenarios show the greatest risk to be in autumn and winter. The threat to infrastructure and buildings includes the assumptions underlying resilience to a ‘once in 100-year event’: these include assuming that the magnitude of such an event is constant, whereas climate change makes this unlikely (UKCIP02). All types of flood may increase:

i  river floods (slow or rapid onset)
ii  flash floods
iii  storm surges
iv  accumulation of rainwater in poorly drained environments
v  coastal and estuary floods caused by tidal and wave extremes

Both inland and coastal flooding may be associated with windstorm events – for example the New Orleans flooding in 2005 in the wake of Hurricane Katrina. Flood risk is related both to water levels and to rate of discharge from the water channel. The frequency of a flood of a given size is known as the recurrence interval or return period, for example 100 years for a flood of 2,500m$^3$/s or 2-2.5 years for the ‘mean average flood’ based on the average of annual floods (UN 1997). In the Netherlands, storm surge warnings and dyke patrols use warning levels, such as when the water rises 2.2m above sea level. It is likely that most flood disasters will continue to be disproportionately concentrated in developing countries, but even smaller scale floods have the potential to affect human health (Section 6).

3.4 Storminess

“...it remains the case that we have little confidence in the simulated changes in the UK wind regime.” UKCIP02

The 120-year data set available for the UK does not show a significant long-term trend in gales, although the highest frequency of severe gales was recorded during the decade 1988 to 1997 (15.4 a year). The average frequency of gales in 1961-1990 was just over 12, including the severe storms of October 1987 and January/February 1990. Overall gale frequency in the winter may decline with climate change. Predictability in the currently available models is poor: for example, it is difficult to predict based on the increased windspeed noted in Wales, NE England and NW Scotland but decreased windspeed elsewhere in UK. Windstorm associated with tidal surge is a particularly deadly combination, as witnessed in 1953 when a high spring tide and steep pressure gradient caused severe flooding in the Netherlands and England.

3.5 Sea and ground water level

Global warming causes thermal expansion of oceans and a rise in average sea levels. Although melting is occurring in the ice sheets of Greenland and Antarctica, it is unlikely that these will make much contribution to sea levels within the next 100 years – in the even longer term, over the current millennium, global warming at the present rate would raise the sea level by several metres (UKCIP02). Uncertainty in the calculation of ice melt, as well as differences in the ocean component in different climate models, has produced varying estimates for
global sea level rise e.g. between 16cm and 69cm by the 2080s on the high emissions scenario. Improvements in modelling the thermal expansion of ocean waters and dynamics of land glaciers were incorporated into the UKCIP02 models, resulting in slightly smaller predicted sea levels for the UK than in the UKCIP98 scenarios. The current rise documented for the UK coastline ranges from 0.7mm at Aberdeen and 2.2mm at Sheerness. The threat of rising sea levels is compounded by the fact that the UK is gradually tilting due to natural land movements: the southeast is sinking while the northwest is rising. Southern Britain is sinking at 1.15mm per year, while northern Britain is rising at 0.5-1mm per year. Storm surges may cause extreme sea level rises, the largest being possible around the coast of SE England, since this is the region of greatest fall in land height and also where the largest changes in winds and storms are experienced. For example, using the medium-high emission scenario, the 2% likelihood of high water level at Immingham (east coast) may rise to 33% by the 2080s (a rise of 60cm in the event of an extreme sea level): at the upper end of the high emissions scenario, the probability of this occurring is about 90% (UKCIP02, 2002).

3.6 Other climate change indicators

Indicators of climate change can be divided into those measuring the state of the environment (temperature and rainfall records, sea level) and those measuring the response to climate shifts, such as egg-laying dates, abundance of butterflies, growing seasons, vector-borne disease and air quality (Table 3.1) (Palutikof, 2007). Other variables that respond to climate shifts include domestic power use, activity in tourism, number of outdoor fires, the seasonal pattern of human mortality and water abstraction for agriculture (Figure 3.8).

Increases in growing season length have been observed in many parts of the world, including western Russia and Fennoscandia in Europe. Data from central Europe suggest an increase of 10 days in the average growing season length since the early 1960s (Parry, 2000). Worldwide, the effect on the growing season will be affected by several factors, such as reduction in water available for irrigation, loss of land through sea level rise and associated salinization. These climate changes have wide potential effects on infectious disease, food production and the ecosystem.

Figure 3.8 Water abstracted for irrigation in England and Wales, 1971-1998

Source: Climate Research Unit (CRU)
### Table 3.1 Responses to climate shifts

<table>
<thead>
<tr>
<th>Variable</th>
<th>How measured</th>
<th>Relevance to climate shift</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural environment</strong></td>
<td>Arrival dates of swallows (measured at 4 coastal observatories, Dungeness, Portland, Bardsey and Isle of Man)</td>
<td>Arrival linked to plentiful supply of aerial insects and warmer spring temperatures – trend since 1970 shows earlier arrival</td>
</tr>
<tr>
<td></td>
<td>Egg laying date of birds (collected by British Trust for Ornithology)</td>
<td>Egg laying linked to food availability hence warmer spring temperatures. 20 of 65 species studied have tended to lay eggs 4-17 days earlier over past 25 years</td>
</tr>
<tr>
<td></td>
<td>400+ series of measurement of trees, corals, ice cores</td>
<td>Show that 20th century warmest in series, with 1990s as warmest decade</td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td>Number of productive English vineyards</td>
<td>Grapes believed to have flourished in warmer climate of Roman Britain: marked upward trend in vineyards in England since 1989</td>
</tr>
<tr>
<td></td>
<td>Water abstraction for irrigation water agriculture, particularly root and vegetable growing; also figures for installation of irrigation equipment</td>
<td>Long-term upward trend in water abstraction, particularly during dry summers (1976/1990/1991/1995)</td>
</tr>
<tr>
<td></td>
<td>Skiing industry in Scotland – measured by skilift and tow passes, also number of days slow at Braemar</td>
<td>Overall downward trend from 1993 (but increase in 1998)</td>
</tr>
<tr>
<td><strong>Behaviour</strong></td>
<td>Number of outdoor fires (almost all caused by human activity)</td>
<td>Gradually rising trend 1980s to mid 1990s, lower incidence 1996-97</td>
</tr>
</tbody>
</table>
Table 3.2  Summary of estimated future climate change for UK (UKCIP02)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change, with variations as predicted by the climate scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Mean UK temperature will increase by 2°C in winter and 4°C in winter by the end of this century (2°C average annual increase on low emission scenario, 3.5°C average annual increase on high scenario). Hot spells to increase by up to 10 days; cold spells to decrease (greatest reduction of around 7 days in Scotland). Heatwaves more frequent after 2030 and more severe after 2060. By 2080, a summer as hot as 1995 will occur in two years out of three, even for the low emissions scenario. Summer drought periods to extend in England and Wales, with summer soil moisture in S E England reduced by 40% by 2080s (high emission scenario)</td>
</tr>
<tr>
<td>Sunshine</td>
<td>Sunnier, particularly in southern England: solar radiation increasing with around 10% less summer cloud cover by 2080s on low emission scenario, 20% less cloud cover by high emissions scenario</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Little overall change in England and Wales; Scotland will be 10% drier and average length of drought likely to increase by 4-6 days in England and Wales. Very dry summers may occur in 30% of years by 2050s and very wet winters (e.g. 1994/5) once every 3 decades (medium-high emissions scenario)</td>
</tr>
<tr>
<td>Snow</td>
<td>Decrease for whole UK – 90% less by 2080s (high emissions scenario)</td>
</tr>
<tr>
<td>Winds and storms</td>
<td>Changes in wind speed uncertain: episodes of very high wind speed possibly will increase in Wales, NE England and NW Scotland but overall decline possible elsewhere in UK</td>
</tr>
<tr>
<td>Sea level</td>
<td>Relative sea level will continue to rise around the UK shoreline (by the 2080s, a rise of between 26-86 cm in SE England; 2cm below current level to 58cm above in Western Scotland (based on whether we meet low or high emissions scenarios by that time). Extreme sea levels will occur more frequently: x10-20 more often for SE England (medium-high scenario)</td>
</tr>
<tr>
<td>Gulf Stream</td>
<td>May weaken, leading to some cooling of UK climate – but considered unlikely to happen within next 10 years and a shut down of the Gulf Stream is not predicted within this century</td>
</tr>
</tbody>
</table>

Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change  

29
4.0 Health impacts: overview

“At the beginning of the 21st century, environmental changes on an unprecedented, global scale have begun to impinge upon human health simultaneously, and often interactively” WHO, 2000

4.1 Introduction

“The traditional approach in climate impact assessment answers the question, “if climate changes like this, what will be the effect on specific health outcomes?” ... In contrast, bottom-up approaches begin with the questions “what aspects of climate change will affect the system?” and “how much climate change can be tolerated?” WHO, 2000

There is a high level of public awareness of global warming, but studies have shown that other social or environmental concerns rank higher as issues of importance. The potential health risks are similarly poorly understood, partly because they are ‘potential’ and not everyday reality for people, particularly in temperate climates such as the UK. The lack of awareness of the links between climate change and health contrasts with the established threat of skin cancer associated with depletion of the stratospheric ozone layer: there is evidence that climate change is perceived as mainly associated with the ozone depletion (Murls and Davies, 2001).

Responsibility for action on climate change is generally perceived to be at the governmental or international level, rather than in individual responses – whether in reducing energy consumption or in planning for climate effects on housing and health. Perceived risk to health appears to determine whether or not individuals will take environmental action (Garvin and Eyles, 1997). From our knowledge of the impact of temperature and rainfall on, for example, infection, it seems likely that early health changes related to climate change will soon be confirmed in the UK. Meanwhile, most health impact assessments focus on the likely trends in future decades. One of the key uncertainties is how we shall cope with the changes: hence ‘coping options’ are built into some health impact models.

4.2 Global environmental health

“At the beginning of the 21st century, environmental changes on an unprecedented, global scale have begun to impinge upon human health simultaneously, and often interactively.” WHO, 2000

The environmental health impact of climate change has to be assessed against the other trends and events, for example the influence of industrial disasters (Chernobyl, Bhopal, Seveso), the likelihood of further pollution accidents, the loss of biodiversity in marine, plant and animal ecosystems, desertification due to aggressive farming practices, increasingly pervasive levels of chemical pollutants in air and water throughout the world. Global changes in human societies are also affecting the environment, for example:

- the worldwide move from rural to urban living
- globalisation of food supplies
- microbial evolution and response to selection in the environment, leading to emerging and re-emerging species
- breakdown in public health measures in many countries, affecting infection control programmes such as for malaria and tuberculosis
- population migration

The soaring level of travel overseas and increasing mobility of populations make it essential to consider global as well as UK perspectives when assessing health impacts of climate change – for example in assessing how quickly malaria could be re-established in a warmer UK, or in the
influence of age-structures and population dynamics on likely energy needs and patterns of ill health.

4.3 Health impact assessments for climate change

The health impact of climate change can be assessed in three ways: spatial, temporal and in terms of complexity, attempting to take account of uncertainties and other factors involved in disease (Table 4.1). Many factors are involved in the cause of diseases and forecasts of the health effects of a single factor, climate change, require careful analysis and interpretation. Surveillance systems to specifically record early human health effects of climate change are still at an early stage and most existing systems need modification or re-analysis to allow comparison with meteorological data – and also to allow assessment of the contribution of non-climate factors.

The time frame is critical for the development of health effects: these depend on the type of climate event, for example the delay before ill health is almost zero for storm induced injury, whereas infections may occur weeks or months later. Our ability to detect changes also depends on the sophistication and speed of surveillance systems: these are well developed for acute infections, but poor for chronic or delayed infection and for impact on other diseases, such as mental health and cardiac disease. Where the ill health response may be due to a wide range of non-climate factors, the ‘detectability’ of a climate response will be correspondingly slow or difficult to interpret.

<table>
<thead>
<tr>
<th>Aspect of health impact</th>
<th>Range/features</th>
<th>Example</th>
<th>Other factors to be accommodated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large spatial scale</td>
<td>national, regional or global scale</td>
<td>Distribution of malaria cases; extent/severity of floods</td>
<td>Population density, food availability; sanitation; quality and access to health care; level of economic development; demographic changes e.g. rising numbers of elderly people</td>
</tr>
<tr>
<td>Long temporal scale</td>
<td>20 to 100 years</td>
<td>Food poisoning statistics and mean temperatures</td>
<td>Changes in diet/behaviour/travel and degree of success of non-climate related control programmes e.g. Salmonella in poultry</td>
</tr>
<tr>
<td>Level of complexity in system</td>
<td>Climate in context of other environmental and social changes</td>
<td>Modelling of impact of climate change on agricultural yield, food supplies and risk of hunger</td>
<td>Multiple uncertainties e.g. behavioural factors; success of interventions; major population upheavals; also dependence on: sensitivity of response to climate change; threshold effects; and sensitivity to non-climate factors</td>
</tr>
</tbody>
</table>

Table 4.1: The three key features of health impact assessment in climate change
4.4 Types of health effects

The potential health effects can be divided into eight broad groups for which baseline data on incidence and cause exist:

1. Infectious diseases: vector borne, waterborne, food related
2. Mortality attributable to heatwaves
3. Mortality attributable to cold periods
4. Malnutrition related to climate effects on food supply
5. Trauma attributable to adverse/extreme weather events
6. Medium and long-term effects of flooding, including mental health as well as infection and impact on other diseases
7. Illness attributable to air pollution
8. Morbidity associated with ozone depletion: skin cancers, cataracts

Three types of methods used to study these categories of ill health:

- **analogue studies** that attempt to describe a climate health relationship (for example correlating variation in interannual malaria incidence in endemic areas with minimum November temperatures) – such studies may involve quantitative comparisons or qualitative assessment, for instance comparing the impact of previous floods
- **empirical studies of early effects** (such as analysis of temperature trends and heat-attributable mortality)
- **predictive models** (for example extrapolating monthly temperature and food poisoning data to estimate the likely increase in cases). Predictive models have been well established for diseases such as HIV/AIDS: for climate change they may involve computing data on vector-borne disease (e.g. malaria) with known distribution of vectors over time and forecasting how these trends will develop

4.5 Predictive modelling of climate change effects on health

Predictive models may be empirical-statistical (e.g. food poisoning and temperature), process/biologically based (e.g. vector studies) or they may involve integrated assessment, where factors in the causal chain are linked with adaptations and adjustments, such as population growth, urbanisation and trends in trade. Few integrated assessment models as yet incorporate health impacts, although a malaria/dengue model has been developed (McMichael et al, 2001). As with all models, there are limitations and difficulties in interpreting the results. One limitation is the relevance – and accuracy – of the historical data entered; another is the limit of pre-existing knowledge. The ideal approach is the process based biological model, where the life cycle of the disease/vectors are fully established and measurable. The large spatial scale of GCM scenarios is an additional limitation. In interpreting the results, it is important to check what baseline has been used and what assumptions have been made about the health data entered, for example in estimating the true current prevalence/incidence of a disease. Finally, the long timescale used in the models is difficult to adapt to the much shorter planning periods used in health and environmental services. Climatologists think in terms of several decades, if not centuries, while the predominant issue for those expected to act on health impact assessments is what will happen within the next decade.
Climate change impacts on health in several ways, depending on location and associated influences on health such as poverty and poor sanitation

4.6 The range of climate related health problems

Climate change impacts on health in several ways, depending on location and associated influences on health such as poverty and poor sanitation (Table 4.2). Climate acts on human health either directly, via heat stress or high wind speed, or indirectly through its effects on ecosystems, the hydrological cycle that determines our water supply, on food species and on disease agents and vectors. While the impact will be inevitably more severe in developing countries and where the water and sanitation infrastructure has been damaged, most of the health problems could potentially occur in the UK. Physiologically, we can adapt to most variations in climate but adaptation is poorer if the fluctuations are short-term or severe. The ‘range of tolerance’ varies between different countries and across regions.

4.7 Ultraviolet radiation and the depleted ozone layer

The ozone layer in the stratosphere absorbs most of the biologically active UV-B radiation from the sun. The ‘ozone hole’ discovered initially by the British Antarctic Expedition at the South Pole in the 1980s, and now also detected to a lesser degree over the Arctic and heavily populated mid latitudes of the southern and northern hemispheres, has caused concern about possible health effects. Until recently, cataracts and skin cancer from increased exposure to ultraviolet radiation (UV) were generally not held to be an example of a climate change effect, but further research has indicated a link between the increase in cases and ozone depletion. Cataracts have been linked to increasing light exposure (Delcourt et al, 2000; McCarty & Taylor, 2002), as have skin cancers (van der Leun et al, 2002). These are important rising health problems in the wider context of global environmental health. Epidemiological studies have confirmed the role of UV in skin cancers: the ozone layer is expected to recover by 2050, but climate change may delay that recovery (Bentham 2001, 2007). Furthermore, increases in temperature may enhance the carcinogenic potential of exposure to the sun’s rays, although as yet the evidence is based on experiments with mice (van der Luen and de Gruijl, 2003).

Sunlight exposure also has health benefits, notably on increasing production of Vitamin D. Increased sunshine due to less cloud cover also has effects on behaviour (good and bad) and on mental health (e.g. decline in Seasonal Affective Disorder (SAD)). International reviews have been published on the depletion of the ozone layer and the slower recovery of stratospheric ozone due to the increased atmospheric halogen burden (WMO, 2003) and on associated health impacts (UNEP, 2003). One of the impacts is on skin cancer in North West Europe, set to rise until the middle of this century. An increase in sunnier days means more sunburn, particularly when these occur in the spring when skin is not acclimatised: sunny weather at a weekend in Southern Chile (close to the Antarctic ozone hole) caused a large increase in sunburn (Abarca et al, 2002). An interesting recent study of beach users in East Anglia showed a strong positive association with ambient temperature, the length of time spent on the beach and the estimated UVB dose received (Horton, 2004). This underlines the importance of viewing climate change effects as a combination of different factors – in this case, between temperature, behaviour and exposure to UV.
\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Change in cloud cover, projection for 2020s (UKCIP02)}
\label{fig:figure1}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Change in cloud cover, projection for 2050s (UKCIP02)}
\label{fig:figure2}
\end{figure}

Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
### Table 4.2  Global health impact of climate change

<table>
<thead>
<tr>
<th>Type of disease/health problem</th>
<th>Location</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vector borne disease</strong></td>
<td>Margins of distribution by latitude and altitude</td>
<td>Tickborne encephalitis/tick bites in Sweden – ticks occurring over wider area; potential increase of ticks in UK; Malaria in highlands of East Africa: potential spread to UK via imported cases/infected mosquitoes</td>
</tr>
<tr>
<td></td>
<td>Potential spread of some vectors to via travel</td>
<td></td>
</tr>
<tr>
<td><strong>Water borne disease</strong></td>
<td>Current endemic areas</td>
<td>Cholera: has re-emerged in several countries. Cryptosporidiosis</td>
</tr>
<tr>
<td><strong>Disease related to marine ecosystems</strong></td>
<td>Oceans, estuarine and coastal populations</td>
<td>Loss of biodiversity encouraging cyanobacteria (blue green algae), also phytoplanktons supporting spread of cholera</td>
</tr>
<tr>
<td><strong>Heat related mortality</strong></td>
<td>Urban populations in developed and developing countries n.b. elderly people especially vulnerable</td>
<td>Increased daily mortality recorded for many cities e.g. from cardiovascular disease/carcinoma, respiratory disease/heat stroke</td>
</tr>
<tr>
<td><strong>Heat related morbidity</strong></td>
<td>All regions</td>
<td>Increase in incidence of diarrhoeal disease and those related to food/hygiene e.g. due to inappropriate food storage</td>
</tr>
<tr>
<td><strong>Trauma from extreme weather events, e.g. storms and floods</strong></td>
<td>All regions</td>
<td>Drowning, increase in infection in developing countries; infection due to overcrowding after evacuation in developed countries; mental health problems; also potential increase in damp housing from heavier rainfall/minor floods</td>
</tr>
<tr>
<td><strong>Sea level rise</strong></td>
<td>Vulnerable populations on low lying islands/coastal areas</td>
<td>Deterioration in ground water quality; diarrhoeal disease</td>
</tr>
<tr>
<td><strong>Malnutrition/interrupted food supply</strong></td>
<td>Vulnerable populations in developing countries</td>
<td>Major impact from floods/droughts in developing countries</td>
</tr>
</tbody>
</table>
5.0 Temperature effects on health

The important message for environmental health is that programmes to reduce cold-related deaths must continue, but that interventions and advice to reduce heat-related deaths should be prepared

When examining the relationship between climate and health, it is important to distinguish those due to the short-term health effects from weather events, from longer term or later ill health. Extreme weather events may be part of natural climate cycles and it is not appropriate to link them with long-term changes associated with climate change, except in terms of the increased frequency or intensity of such events.

5.1 Health impacts of heatwaves

The climate term for a heatwave is an ‘extreme high temperature episode’. These used to occur only once every 350 years, but could occur every 5-6 years under the anticipated warmer climate due by 2050 (Donaldson et al, 2001). The European heatwave of 2003 was the hottest in at least 500 years: more than 20,000 people died as a result of heat stress, with particularly high fatalities in the elderly. Temperatures soared throughout Europe: in the UK, 38ºC (100ºF) was topped for the first time since records began (Hacker et al, 2005).

There is a 1 in 40 chance that by 2012, Southern England will have experienced a severe heatwave causing 3000 immediate heat related deaths and 6350 other heat related deaths (Donaldson and Keatinge, 2007). While few deaths to date have been certified as heat related, studies, for example of the heatwave in 30 July-3 August 1995, have shown excess mortality and an international surveillance scheme is collecting deaths from cities around the world: there is evidence that urban populations are much more at risk. Death is more likely to occur in the elderly or chronic sick, but a number of underlying causes are involved (Table 5.1). A study of the 1995 heatwave in Chicago showed that death rates are higher in the bed ridden, isolated people unable to care for themselves and those without air conditioning (Semenza et al, 1996). Preliminary analysis of data for London during that heatwave suggested that excess mortality was higher in deprived populations (Donaldson et al, 2001). One of the problems in explaining the wide range of excess deaths is that high temperature episodes are often associated with high pollution episodes. In addition to the broad categories of causes of death, many diseases are exacerbated by heat, for example endocrine disorders (e.g. diabetes), skin disease and infections. Drug therapy such as antidepressants impair heat tolerance, as does alcohol.

Table 5.1 Causes of heat related mortality

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Heat associated factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary thrombosis</td>
<td>Dehydration, loss of salt and water; increased blood viscosity</td>
</tr>
<tr>
<td>Cerebral thrombosis</td>
<td>Decreased ability to adjust to temperatures; dehydration</td>
</tr>
<tr>
<td>Carcinomas</td>
<td>Association with increased air pollution during heatwave; vulnerability to heat in old age plus possible drug interference with homeostatic mechanisms</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td></td>
</tr>
</tbody>
</table>

In all cities studied, deaths increase once temperature has risen above a certain threshold, depending on the region. In the UK, heat-related deaths begin to occur when the daily mean temperature rises above the minimum mortality band of 15.6-18.6ºC. In the current climate conditions, an estimated 800 ‘heat-related’ deaths occur annually. Under the medium-high climate change scenario, heat-related
deaths would increase to an estimated 2800 annual deaths in the 2050s, unless preventive measures and changes in lifestyle allow improved adaptation (Donaldson et al., 2001). The adverse effects of heat would occur during 35 days a year on average by the 2050s. Excess death rates would be highest in people aged 75 or more, but would be expected to increase for all age ranges. However, an analysis of mean annual heat related mortality 1971-2003 did not show an increase as summers warmed, implying an increased population tolerance to heat – although mortality is expected from an extreme heatwave (e.g. averaging 27ºC) (Donaldson and Keatinge, 2007).

Overall for the UK, climate related deaths would fall because of the increasingly mild winters. Currently around 80,000 die from the effects of cold in the winter, with UK having the highest rate in Europe. Contributory factors include fuel poverty, a tendency to have cooler homes and to wear less appropriate clothes outdoors during cold weather. Studies of excess deaths during cold spells suggest that coronary thrombosis and respiratory infections are major underlying causes. These deaths would be expected to decrease to around 60,000 annually by 2050. Measures to mitigate climate change, such as improved house insulation to conserve energy, may further decrease the number of cold-related deaths.

Both heatwaves and cold spells are associated with increased levels of hospital admissions, as well as deaths. The important climate change message for environmental health is that programmes to reduce cold-related deaths must continue, but that interventions and advice to reduce heat-related deaths should be prepared.

### 5.2 Evidence of climate change effects on infection incidence and distribution

Climate change is already affecting infection patterns, although in the UK the evidence is limited mainly to food poisoning. In an era of increasing travel to areas with a high prevalence of infection, we need to consider the impact of imported infection as well as the potential for spread of disease vectors to the UK when the climate allows their survival.

#### 5.2.1 Food poisoning

Increased survival of microorganisms in warmer ambient conditions would be expected to cause more food poisoning, in association with eating outdoors or due to storage in warm conditions. A correlation has been demonstrated between notified food poisoning and temperature in the UK (Bentham and Langford, 1995; Bentham, 2001) and with Salmonella infections (Kovats et al, 2004). Given the current level of food poisoning notifications, an increase of 1ºC (expected in the next 20 or so years) would produce ~4,000 additional notifications. Due to under reporting, the real level of additional cases could be around nine times this figure.

In countries with very high levels of diarrhoeal disease, these trends may be harder to detect, but they are likely to increase both survival and spread of microorganisms that thrive in dirty water or poor sanitation. Studies have shown a lag between high temperatures and the effects on humans, suggesting a role for warnings to be given to the public about the increased risk of foodborne disease during hot weather (Bentham, 2007). The evidence is strongest for food poisoning due to Salmonella infection (D’Souza et al, 2003; Kovats et al, 2004). In the European study by Kovats et al, strongest effects were found for temperatures 1 week before the onset of
illness. The study by D’Souza examined monthly salmonellosis notifications and temperature, finding a significant association for a lag of one month between mean temperature and cases of salmonellosis. As yet there is insufficient evidence to estimate the potential effects on Campylobacter infection. A study of Campylobacter infection in Denmark found a significant positive association with temperature, with strongest effects using a lag of 4 weeks: prevalence of the infection in broiler flocks at slaughter was positively associated with temperatures 3 weeks previously. However, a study of 13 European countries (Kovats et al, 2005) did not show a strong temperature effect on subsequent Campylobacter infections. Transmission of Campylobacter may be affected by factors in addition to temperature, such as the size of animal reservoirs and vectors such as flies (Nichols, 2005).

5.2.2 Vector borne disease: malaria, tick borne encephalitis, Lyme disease

Malaria
The climate change impact on insect vectors will depend on the complex relationship between host, vector and parasite, including the temperature and other conditions required for breeding and survival. The malaria parasite needs a high average minimum night temperature to complete its life cycle: few parasites develop in mosquitoes below 15ºC. Worldwide, changing temperature patterns are favouring the needs of these parasites, with evidence of infected mosquitoes at higher altitudes and over wider areas and corresponding changes in malaria prevalence. Some 300-660 million clinical cases occur annually and is probably rising, of particular concern because of the increasing spread of drug-resistant strains of the parasite.

Malaria was common in marsh communities of the Fens and Southern England between the 16th and 19th centuries, petering out in the early 20th century thanks to various control measures such as drainage schemes and improved housing. Increasing temperatures make it possible that indigenous malaria may be re-established in the UK, particularly local outbreaks of Plasmodium vivax malaria (Rogers et al, 2001), since the mosquitoes capable of carrying the both temperate and tropical strains of vivax malaria are already present and P vivax survives at lower temperatures than P falciparum, the cause of the more

Box 5.1 Temperature increases and food poisoning

The food poisoning risk will increase with climate change, accelerating the already established seasonal variation:

- increased multiplication of pathogens at high temperatures e.g. Salmonella growth occurs above 7ºC, optimum at 37ºC and Campylobacter growth increases above 30ºC
- higher temperatures also increase rate of infection in animals (e.g. multiplication of bacteria in animal feeds), thus adding risk to the food chain
- change in food eating behaviour e.g. more barbecues and outdoor eating
- studies have shown that food poisoning rates correlate with temperature a month earlier, consistent with time taken for food chain to be affected and cases to emerge
- a mean temperature increase of 1ºC (expected over next 20-30 years) is estimated to increase food poisoning by 4.5%, with a higher risk of that due to Salmonella of ~12.5% (Kovats et al, 2004). An increase of 2ºC would increase food poisoning notifications by 9.5%, while an increase of 3ºC would raise them by 14.8% (Bentham, 2001)

- The evidence is sufficiently strong for public warnings about food poisoning to be considered during hot weather periods: Salmonella is strongly related to temperature in the range 7-37ºC and the common threshold for the 1 week lag effect in the study of 13 European countries (Kovats et al, 2004) was 6ºC
serious form of malaria. Areas next to extensive wetland would be most affected as in the historical endemic malaria in England and Wales. In the medium-high climate change scenario, several areas of the middle and southern UK would allow P.vivax transmission for 3-4 months a year by 2020: the main shift from present day potential for vivax malaria is from 2-3 months a year, mainly in East Anglia and South East England but also spreading northwards to the Scottish Borders.

It is highly unlikely that P.falciparum could be established in the UK with the current climate change scenario estimates. However sporadic cases and outbreaks of ‘airport malaria’ may increase, particularly during long spells of hot weather: 14 such cases were reported between 1969 and 1996 (Gratz et al, 2000), although it is reassuring that a survey of 52 aircraft arriving at Gatwick from Africa (25 % of all night flights from Africa) revealed no malaria mosquitoes on board (Hutchinson et al, 2005); this suggests that current disinfection practices for planes arriving from the tropics is effective. Also travellers’ malaria is likely to increase due to the greater abundance of mosquitoes in endemic areas. Currently over 2000 cases of travellers’ malaria are reported each year to the PHLS Malaria Reference Laboratory, with a steady increase since the mid 1970s.

New vector species for malaria could become established in Britain, including the European vectors of P.vivax, such as An.saccharovi, An.labranchiae, An.Superpictus and An.Sergentii. However, summer droughts would limit the breeding sites and the risk is considered very low and small scale. Meanwhile, there may be a need to give advice on controlling breeding sites (such as water butts) or windows open at night during hot weather not associated with droughts. NHS Direct reported a 22% increase in people calling for advice about mosquito bites in the summer of 2007: attributable perhaps to a mixture of heightened awareness and increased breeding sites following the flooding.

Ticks and other vectors
The risk of disease from tick bites, such as tick borne encephalitis (TBE) and Lyme disease (Borelia species transmitted by the tick common in Europe, Ixodes ricinus) is harder to estimate. Warmer weather favours the spread of ticks, but they prefer dry conditions and overall it is possible that tick borne encephalitis would decrease in central Europe. While human contact with ticks may increase due to changing land use for agricultural purposes, none of the predicted climate changes suggest that the UK will be threatened by TBE (Rogers et al, 2001, 2007). A marked upsurge in TBE occurred in some Baltic states (such as Latvia and Lithuania) in the early 1990s following the end of Soviet rule: after analysis against climate parameters, it was concluded that much of the change could be attributed to the socio-economic transition (much more mobility, job variation), related increases in the abundance of rodents on which ticks feed, surveillance differences and greater opportunity for exposure, such as increased outdoor recreation in forest areas. However these authors also observed that warmer springs would facilitate earlier onset of tick activity and drier summers favour ticks, so climate-induced tick increase cannot be ruled out.

Other vectors that may be affected by climate change include fleas, cockroaches, stinging insects, midges, non malarial mosquito vectors (e.g. those carrying West Nile Virus) and the caterpillars of some moths that can induce an allergic reaction on contact with human skin (Box 5.2).
In developing countries, cholera increases have been related to climate change, raising concerns of an 8th pandemic of cholera being triggered.

**Box 5.2 Insects and other vectors that may increase in a warmer UK**

- Indigenous and imported mosquitoes: e.g. increase in West Nile Virus, predominantly an infection of birds transmitted by Culex, Aedes and some other species of mosquitoes, reported in parts of Europe and USA. While 80% of people show no symptoms, a small (~1%) percentage develop a severe infection with encephalitis or meningitis.
- Increasing levels of the ‘midge menace’ may be an issue in tourist areas (and midges blown across from the continent were implicated in the recent epidemic of bluetongue disease in the UK).
- House dust mites would also be expected to increase under warmer conditions.
- More sinister but much less likely insect vectors that could be re-introduced in a warmer climate include the fleas responsible for plague, associated with an increase in rodent populations or migration of rats to higher/different areas following flooding. Similarly, Weil’s disease (leptospirosis) could increase in association with higher rodent populations, since it spreads via rat urine and faeces.
- Of lesser severity, but with high likelihood for the UK, is the likely increase in fleas on cats and dogs in warm conditions: cat fleas in particular will bite humans when hungry.
- Blood sucking black flies, such as the Blandford Fly, could become more common, particularly in southern England.
- Stinging and biting insects (including bees, wasps, horseflies, hornets) will be more numerous. Greater exposure may increase the number of people who become sensitised and at risk of a severe allergic reaction.
- Nuisance flies (the ones that cluster around buffets and kitchens in warm weather) are going to increase, with the associated risk of contaminating food and surfaces with bacteria.
- Caterpillars (of moths) will be more abundant: some species (urticaceous caterpillars) cause painful swellings and rashes on skin contact, and may also cause allergies.
- Stegomyia albopicta (Aedes albopictus), a mosquito that can be a vector of dengue fever and malaria, has recently been introduced to the USA via used car tyres. We need to be alert to the potential for the introduction of such new species to the UK.

**5.3 Water-related disease and climate change**

Changes in the hydrology and water ecosystems are likely to favour the survival and breeding for some organisms that can cause disease. Current evidence of climate effects is based on seasonal variation in water-related infections such as those due to Cryptosporidium parvum, Giardia lamblia and microsporidia. These organisms are also present in higher numbers after heavy rainfall. Extreme rainfall events were statistically significantly related to monthly reports of outbreaks of Cryptosporidium and Giardia infections in a study in the USA. Increases associated with heavy rainfall have also been observed in the UK: the increased surface water turbidity caused by heavy rain would lead to higher numbers of indicator bacteria and pathogens, posing a challenge for water treatment works, particularly those abstracting directly from rivers. Slower river flow during periods of decreased rainfall/drought would increase pathogen concentrations due to less dilution of effluent discharges, although higher exposure to the anti-microbial effects of sunlight on surface waters could help to balance this. Water treatment could also be affected via less efficient chemical coagulation at higher temperatures, with consequent reduction in removal of microbes by clarification and filtration (Hunter, 2003; Nichols et al, 2003). In developing countries, cholera increases have been related to climate change, raising concerns of an 8th pandemic of cholera being triggered. The current UK infrastructure should prevent indigenous cases of cholera, although an increasing number of cases may occur in travellers returning from endemic countries.

The influence on water related outbreaks is hard to predict, given the contribution of other factors, including the reduction in...
livestock in the wake of the 2001 UK Foot and Mouth outbreak. Algal blooms (cyanobacteria) are likely to increase and to raise issues about toxic effects if the cyanobacteria and their toxins penetrate treated water supplies: the health problems associated with cyanobacteria range from skin irritation to severe systemic disease. However, there is little direct evidence that *Aeromonas hydrophila* and other organisms commonly found in water distribution pose a significant threat to health. Drinking water quality is more vulnerable in warmer climates and the current low level of reported outbreaks may reverse, particularly in association with larger private supplies. The increased consumption of bottled water in warm weather could produce problems due to contamination, multiplication during storage and re-use of containers. In addition, water shortages and standpipes during drought periods could indirectly increase infections due to difficulties in maintaining hygiene.

Upland sources in peat-covered catchments would contain higher levels of dissolved organic carbon, giving a potential risk of trihalomethane formation on disinfection with chlorine. This would be more likely after dry periods. Drought has so far not been a significant health problem in the UK, but frequent droughts, particularly in coastal areas and at the end of water distribution systems, could raise the possibility of increased ingress of microorganisms into pipes and water reservoirs.

In addition to greater vigilance for waterborne pathogens, water-associated diseases such as legionellosis (Legionnaires’ disease) is likely to increase due to the increased use of air conditioning and humidifiers in warmer climates. Swimming pool outbreaks have recently increased in the UK (particularly due to *Cryptosporidium* spp – and usually related to factors such as faecal accidents or poor pool maintenance) and climate change would be expected to increase leisure associated water problems, including drowning and other trauma as well as infection. Wider leisure use of untreated fresh and marine waters would raise issues about sewage discharges and animal contamination, since pathogens could survive for longer periods in warmer waters.
6.0 Health impact from floods

The flood risk to humans can be defined as a product of flood hazard and vulnerability – where vulnerability includes both susceptibility and the ability to resist disease or to recover from it.

6.1 While there is no firm conclusion on the frequency of flooding related to climate change, there is agreement that floods may change in pattern and intensity, with effects on water quality and supply, access to health care, food supply and both direct and indirect health effects. The epidemiological evidence for health effects is limited because of the relatively small number of studies, problems with study design, clear hypotheses and appropriate control groups and other factors. In general, only major devastating floods have been used to study effects, for example the flooding of the Yangtze river in China in 1996, with more than 3000 deaths, over a million people evacuated, 5 million homeless and 100,000km² of land under water. Over 98% of the deaths attributed to floods between 1900 and 2004 occurred in Asia; and around 20% of all natural disaster deaths for this period were flood-related (Few et al, 2004). The floods in Europe have been on a relatively small scale, with few deaths, so it is easy to underplay the potential effects of floods. It has been proposed that all floods, of any size, impact upon human health (Few et al, 2004).

Few effects have been observed in the UK to date, partly because of a good health, water and sanitation infrastructure and partly related to a well-nourished and generally fit population. Mental health and long-term physical health effects predominate in northern countries and infection hazards predominate in southern developing countries: this difference could be due to different study design and the factors measured, as well as to socio-economic and sanitation differences.

6.2 The range of health risk from floods

The flood risk to humans can be defined as a product of flood hazard and vulnerability – where vulnerability includes both susceptibility and the ability to resist disease or to recover from it. Flooding carries a range of potential immediate, intermediate and long-term direct and indirect health risks, wherever a flood occurs, although classifications by timing of onset can be misleading as some risks pertain to both the onset of a flood and its aftermath (Table 6.1).

A flood disaster can be sudden, or develop slowly but relentlessly over several weeks. This affects both the way the disaster is identified and managed and the timescale of the health effects, for example in the number of injuries and deaths caused by a rapidly advancing flood. It also has implications for epidemiological evidence: the strongest evidence remains the obvious directly attributable effects of drowning or physical trauma.
### Table 6.1  Summary of potential health risks from floods

<table>
<thead>
<tr>
<th>Timing</th>
<th>Type of potential risk</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate:</td>
<td>Injuries from debris; drowning</td>
<td>10 people killed and 22 injured in European floods 1900-2004; in Asian floods over same period, 6,757 deaths and 1,177 injuries¹. A survey of flash floods reported 43% being car related (trapped, swept away) (French et al, 1983)</td>
</tr>
<tr>
<td>pre-onset and onset phase</td>
<td></td>
<td>Other injuries: Electrocution from unsafe electrical wiring</td>
</tr>
<tr>
<td></td>
<td>Heart attack</td>
<td>Due to shock or physical strain, e.g. in a review of flash floods (French et al, 1983) and in a man shifting sand bags during the floods in England, June 2007</td>
</tr>
<tr>
<td></td>
<td>Exposure to chemicals/toxic gases</td>
<td>Chemical contamination of food and water supplies; in Puerto Rico in 1990 a person died because the exhaust pipe of the car was blocked by mud (Staes et al, 1994). Carbon monoxide poisoning affected 51 people after Hurricane Katrina (MMWR (2)) – mainly linked to use of portable generators; and two men died in Gloucestershire in July 2007 while attempting to repair a generator during the flooding</td>
</tr>
<tr>
<td></td>
<td>Exposure to pathogens</td>
<td>Faecal-oral infections, rodent-borne infections such as leptospirosis, respiratory and skin infections; infections from helminths in the soil in tropical regions²</td>
</tr>
<tr>
<td></td>
<td>Impaired capacity of health care systems</td>
<td>Reduced access to essential health care</td>
</tr>
<tr>
<td></td>
<td>Damage to property</td>
<td>Injuries</td>
</tr>
<tr>
<td></td>
<td>Evacuation</td>
<td>Infections due to overcrowding/poor facilities/reduced ability to maintain good hygiene</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Mental health</td>
<td>Also affected during earlier stages e.g. 43 suicide attempts in the 6 weeks following Hurricane Katrina 2005 (MMWR, 2006)</td>
</tr>
<tr>
<td></td>
<td>Exposure to pathogens</td>
<td>As in immediate phase. Cholera and polio amongst several others raised after flood in developing countries; also malaria due to enhanced opportunity for breeding and transmission. A cluster of minor infections after Hurricane Katrina were attributed to conditions in temporary shelter</td>
</tr>
<tr>
<td></td>
<td>Malnutrition</td>
<td>Reduced access to safe food/damage to crops</td>
</tr>
<tr>
<td>Long-term</td>
<td>Mental health</td>
<td>Observed in post-flood studies in Australia and UK (Ohl, 2001) in the 12 months after a flood</td>
</tr>
<tr>
<td></td>
<td>Physical health</td>
<td>Exacerbation of existing health problems, higher rate of mortality from existing ill health – observed in studies of floods in northern countries, possibly masked by higher incidence of other problems (infection/trauma) in developing countries</td>
</tr>
</tbody>
</table>

**Notes to table**


² the list of potential infections includes all the recognised water-related infections, food poisoning, rotavirus, norovirus etc – to date, not reported as raised following UK floods but the potential is indicated by the rise in reports of some organisms, notably Cryptosporidium spp, following periods of heavy rain
Infections and epidemics following floods

The health effects of water disasters are usually due to the lack of prompt restoration of public health services and interventions, with the resulting risk of epidemics and other ill health. Studies in the UK and USA suggest that infection problems are rare: the indirect nature of the risk means that they are also extremely difficult to quantify or attribute to the flood. Active case searching after Hurricane Katrina and flood in southern USA in August 2005 has provided strong evidence of the infection risk after a combined storm and rapid flood. A cluster of Vibrio organisms were attributed to flood water and other environmental exposure. The cluster did not include Vibrio cholerae 01, or other toxogenic subtypes that cause the disease of cholera, but five deaths occurred in the 22 cases identified within 2 weeks of the hurricane and associated flooding (MMWR (1), 2005). The danger was greatest from Vibrio vulnificans skin infections as these can rapidly progress to septicemia, highlighting the need for prompt cleansing of wounds and early antibiotic therapy if this organism is suspected. The other infection risk identified was related overcrowding during temporary shelters: a Norovirus outbreak was reported in Houston, Texas among evacuees, 24,000 of whom had been housed at a sport and convention complex. Over 1100 (18%) evacuees developed acute gastroenteritis requiring treatment: 50% of their stool specimens were positive for Norovirus and no other enteropathogen was found. Lack of adequate hand washing facilities and of clean toilets, plus delays in decontaminating soiled areas and bedding were all identified as contributory factors (MMWR (3), 2005). Overall, the surveillance identified 10,047 hospital visits within 2 weeks of the event and 27,135 related hospital visits in the subsequent month (MMWR, 2006). The most common illnesses were skin or wound infections, followed by upper respiratory infections, skin rashes, insect stings or bites and lower respiratory infections.

Floods in malaria-endemic zones increase the risk of malaria transmission: although there can also be a temporary reduction in transmission due to breeding sites being washed away, but after the flood the stagnant or slow moving water provides ideal breeding opportunities, as do blocked drains. For the next two decades, malaria is not anticipated to return to the UK, although breeding of other potential insect vectors following floods could become a matter of concern, particularly when these occur during warm weather. A risk more likely to increase in floods during the next few years is that of rodent-borne disease. Flood-related outbreaks of leptospirosis have been reported in several developing countries, notably those in South America.

Chemical pollution and floods

Flooding of industrial plants and waste storage facilities can cause short-term or persistent pollution of water supplies. Structural damage during a flood may result in the release of fuel oil into floodwater – with the risk of toxic hydrocarbons being released into the indoor air (Potera, 2003). Rapid dilution by the flood waters usually reduces the risk; and environmental studies have not in general shown serious levels of contamination. Carbon monoxide poisoning deserves particular mention: it was the cause of fatalities in the UK summer 2007 floods and surveillance systems established after floods in the USA have identified several cases (Table 6.1).
Adults whose homes were flooded had four times more psychological distress than those with unaffected homes

6.5 Mental health problems associated with floods

Mental health includes a wide range of concepts, including those determined by cultural differences. Major stresses in life can affect mental health (for example, subjective well-being, perceived self-efficacy, autonomy, competence), increasing susceptibility to both physical and mental illness. There were 43 recorded suicide attempts following Hurricane Katrina (MMWR, 2006) but the types of mental ill health reported after floods include less severe depression, anxiety, increased alcohol dependence or drug misuse and exacerbation of existing mental health problems at all ages. Comprehensive data are not yet available from studies of the June-July 2007 floods in England, but the town centre flood of Lewes, Sussex on 12 October 2000 was investigated by a case control study 9 months after the event (Reacher et al, 2004). People affected were evacuated for a median of six months, with a minimum of 10 days. Adults whose homes were flooded had four times more psychological distress (RR 4.1, p<0.0005) than those with unaffected homes (Reacher et al, 2004). In this study, mental health was measured in broad terms using telephone interview answers to the General Health Questionnaire (GHQ-12) and responses were also studied in terms of the flood depth experienced. Other symptoms significantly associated with flooding included earache, but slight increases in gastroenteritis, skin rash and injury were not statistically significant: risk estimates for all physical effects declined after adjusting for psychological distress.

A study of the 1968 severe floods in Bristol found a significant increase of new psychiatric symptoms in women. Mental ill health did not increase significantly in men, in contrast to the results of a study of the 1974 Brisbane floods, in which flooded men had more mental illness than non-flooded men. A follow-up study more precisely identified the incidence of psychiatric symptoms as highest in men aged 35-75 and women under 65: there was no difference in symptoms for men and women aged over 65 years. Case control studies after Tropical Storm Agnes (1972) did not show a significant difference in mental health symptoms, but a later study of flooding effects elsewhere reported increases of depression and anxiety, as well as increased physical symptoms (Phifer, 1990). Not surprisingly, low-income people appear to be more vulnerable to the adverse effects of floods; and, where children have been included in post-flood studies, there is evidence of changed (more aggressive) behaviour and of higher incidence of depressions and post-traumatic stress disorder (PTSD). PTSD is characterised by problems such as intrusive memories, sleep disturbance, irritability and anger. Severe mental health effects, such as suicide and schizophrenia, have been reported, for example from China after extreme flooding, but there is insufficient good quality epidemiological research to support a confirmed link with flooding or other natural disasters.
7.0 Health impact from windstorms and air quality changes

The storm in January 1990 had a higher death toll because it occurred during daytime working hours, although with a peak at 9am many people were able to avoid travel or going out.

7.1 In the UK we have a higher frequency of gales than continental Europe, for example a current level of about 32 (small) tornadoes each year in the UK, mostly in England. Temperate windstorms involve strong winds occurring across a track up to 1000 km wide. Tropical windstorms (cyclones) involve very high wind speeds restricted to a relatively narrow track, about 150 km wide. Updated climate change scenarios for the UK show less certainty that windstorm frequencies will increase as there is considerable natural climate variation in gales, for example there were several years in the late 19th and early 20th century when severe gales occurred. While there has been a recent increase in gale frequencies over the British Isles, there is no convincing evidence that this is related to human-induced climate warming (Hulme et al, 2002), as indicated in the UKCIP02 scenarios (Figures 7.1-7.2): these show increases but no significant difference for the different emission scenarios. If the recent increase is due to natural variation, it is still a matter of concern, because of the damage and injuries caused by high winds (Box 7.1).

Box 7.1 The effects of high wind speed

Severe storms can involve wind speed in excess of 90 knots: even at lower speeds there is damage to structures and increases in injuries to pedestrians from flying debris. The proportion of vulnerable housing stock varies from 2% of high-rise flats to 28% of terraced houses. The frequency of damage rises steeply with wind speed, e.g. a 5m/s increase from 40m/s to 45m/s could cause a five fold increase numbers of damage incidents. Collapsing garden sheds, upturned vehicles and uprooted trees also pose a significant risk to health.

The health hazards of storms vary with the season and with the time of day. The storm of 15-16 October 1987 was associated with an estimated 21 deaths and relatively few injuries (2287 reported), despite affecting 25 million people and their homes – this was largely due to the maximum intensity occurring at 2-6am. The storm in January 1990 had a higher death toll because it occurred during daytime working hours, although with a peak at 9am many people were able to avoid travel or going out (Baxter et al, 2001). Heavy clothing in winter increases the risk of people being blown over (increased drag coefficient), especially in streets and by corners of buildings. In addition, damage to power lines and utility poles would be likely to disrupt communications and power supplies.

The current mean annual incidence of wind-associated deaths in the UK has been estimated as six, with 144 non-fatal injuries. A large proportion of these are associated with traffic accidents, followed by accidents from building failure, falling chimneys, roof elements and walls. While road traffic injuries appear to be a high risk and associated with the severest injuries, being blown over is also a notable cause of injury in storms. During a severe storm in Leeds in 1983, the majority of accidents occurred when people walking outside were blown over. All age groups were equally affected. Injuries caused by gales include head injuries, fractures, foreign bodies in eyes, bruising and lacerations. The load on health care facilities could disrupt other treatment.
Projected windspeed changes for 2020s (UKCIP02)

Projected windspeed changes for 2050s (UKCIP02)

Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
7.2 Health effects of air pollution with a changing climate

In general, health effects due to air pollution will decrease with the types of climate change predicted. This is because the warmer winters will reduce episodes of cold. Also, the expected reduction in emissions of particles, oxides of nitrogen and sulphur dioxide will decrease both the mean annual and episodic winter ambient concentrations of pollutants. The adverse health effects associated with air pollution, such as exacerbation of asthma and other lung disease by ozone, sulphur dioxide and nitrogen dioxide, and of pollution-enhanced invasion by micro-organisms, are estimated to decrease by about 50% (Anderson et al, 2001). Reduction in ambient levels of aromatic hydrocarbons could also have a beneficial effect on cancer incidence.

On the other hand, summer pollution may increase, particularly on hot sunny days. Increased background levels of ozone in north west Europe may also exacerbate diseases such as asthma and a possible causative role of ozone in asthma has recently been suggested. Ozone episodes are most likely to occur in warmer climates. During a heatwave, particle concentrations as well as ozone are elevated: the high concentrations during the hot summer of 1976 was associated with increased mortality of 9.7% in England and Wales and 15.4% in London. Health effects have also been measured in terms of increased health care utilisation, impaired lung function, exacerbation of heart disease and increased frequency of a wide range of symptoms. The net increase in ozone episodes is likely to be small, but associated with an estimated increase of premature deaths of 10% by 2020 and 20% by 2050 (Anderson et al, 2001). Reduction in precursor pollutants may explain the recent reduction in the intensity of ozone episodes in the UK (the last severe fog in London occurred in 1975).

The increase in the growing season could increase the level of pollens, known to exacerbate asthma and hay fever. Threshold values for the link between pollutants and disease are difficult to define, partly because of wide individual variation in resilience to pollution effects.
8.0 Mitigating climate change

...to adapt to climate change we need to design resource and management systems to cope with the changes and the emerging climate change impacts.

8.1 A report in 2007 from the House of Commons Environmental Audit Committee identified climate change as being on a different scale from any other political challenge, claiming that its potential effects “could be both physically and economically devastating”. We can mitigate climate change by pursuing options for emissions reductions; to adapt to climate change we need to design resource and management systems to cope with the changes and the emerging climate change impacts. The ideal is to pursue both: for environmental health, the most pressing issue is adaptation and preparation for climate impacts. This is partly because of the delayed effects of mitigation, and partly because the long drawn out negotiations on mitigation suggest the value of a pragmatic approach. The current government emphasis is on mitigation, for example by the Climate Change Levy, the establishment in 2008 of the Department for Energy and Climate Change (DECC) and the 2007 Climate Change Bill – the first legislation of its kind in the world. There is an unintended irony that those working in environmental health are going to need to spend time on adapting to many of the current and proposed mitigation measures: there is already a formidable list of regulations specifically targeted at climate change, with more likely when the draft Climate Change bill is added to the statute (Box 8.1).

8.2 European Commission position on climate change

The Commission of the European Communities (EC) produced a green paper on adapting to climate change in June 2007, warning that only “early, deep cuts of greenhouse gas emissions” will reduce severe climate change impacts and that adaptation is essential but not an alternative to these cuts. Up to a third of plant and animal species are assessed by the EC to be at risk of extinction with an anticipated global temperature rise of 1.5-2.5°C, prompting another EC communication in January 2007 ‘EU Action Plan to 2010 and beyond’ on limiting the change to 2°C and implementing the 2006 Biodiversity Plan. The UK is not currently identified as amongst the most vulnerable areas of Europe to the impacts, except through the dense population of flood plains. The cost of adaptation for Europe will however be shared by the UK and it is estimated that changes to infrastructure and buildings could amount to 1-10% of the total invested in construction. The urgent mitigation is seen as the only alternative to “reactive unplanned adaptation” when crises such as floods and heatwaves arise. Consumer protection, public health and food and feed regulations will all be reviewed for whether they are ‘proofed’ against climate sensitivity. The EC is also working towards a global market for environmental technologies, fostering trade in sustainable goods and services. In the mean time, member states are committed to reducing carbon emissions and to trading carbon emissions while they try to reach targets.

Box 8.1 Regulations/relevant air legislation on mitigating climate change (for more information, see the Environment Agency website www.netregs.gov.uk/netregs)

Building Regulations 2002, 2005, 2006, including condensing boilers update
Climate Change and Sustainable Energy Act 2006
Climate Change Agreements (Energy-intensive Installations) Regulations 2006 SI 59
Climate Change Agreements (Eligible Facilities) Regulations 2006 SI 60
Climate Change Agreements (Miscellaneous Amendments) Regulations 2006 SI 1848
“It became apparent at the outset of the Review that the UK was going to miss its domestic target to reduce carbon emissions by 20% by 2010.”
Report from House of Commons Environmental Audit Committee, July 2007

8.3 The Climate Change Bill

“It became apparent at the outset of the Review that the UK was going to miss its domestic target to reduce carbon emissions by 20% by 2010.”
Report from House of Commons Environmental Audit Committee, July 2007

The Stern review in 2006 reviewed the government’s Climate Change Programme and found it wanting: estimations of the impacts of carbon reduction policies had to be revised downwards to around half of the projected 20% target. Meanwhile, the UK had become committed to Phase II of the EU Emissions Trading Scheme, which requires member states to meet targets while allowing some trading between high and low emitting states. The Climate Change Programme was established in 2000 to present a package of policies designed to meet the elusive goal of 20% less carbon emissions. The Department of Trade and Industry (now Department for Business, Enterprise and Regulatory Reform) has modelled the future development of energy supply and demand, based on:

- **fossil fuel prices** – which affect demand and also the mix of energy supply
- **economic growth** – higher incomes lead to more consumption and production, which increases emissions; emissions also increased by greater growth in manufacturing than in service sector
- **demographics** – increases in population and size of household tend to increase consumption, production and travel and hence emissions

Carbon reduction policies were factored into this model, for example the Climate Change Levy, essentially an energy tax. The Climate Change Bill aims to address the findings of the reviews and models (Box 8.2).
Adaptation is included in the Bill amongst its provisions, although the requirement is for regular progress reports rather than any specific targets or funding. A possibly idealistic assumption of the Bill is that global warming is an international issue, requiring all countries to make significant efforts to curb their emissions (see notes on Kyoto Protocol in the Glossary). As the Climate Change Bill is the first attempt to create a legal framework, the UK is seen to be “leading by example”, with the rest of the world “watching the UK’s ‘experiment’” (House of Commons Environmental Audit Committee, 2007). The short-term health benefits of the mitigation measures include, for example, improving health via encouragement of cycling and walking or in reducing fuel costs and poverty by fostering more efficient energy use in indoor environments. Climate change and emissions agreements could also accelerate the long waited assistance to local authorities to address the backlog of housing repairs and demand for home insulation.

8.4 Progress with the Kyoto Protocol

The Kyoto Protocol on greenhouse gas emissions was signed in December, 1997 but has not been ratified by all signatories, notably the USA. The UK government has agreed a target of 12.5% reduction in greenhouse gas emissions from their 1990 level by 2008-2012, with the aim to reduce CO₂ by 20% by 2010. The achievement of these targets involves a wider framework of strategies for sustainable development, integrated transport and energy. While governments continue to negotiate and work out these strategies, the control of emissions, however essential for the future, will have little impact within our lifetimes. Even if the overall Kyoto target of 5.2% less emissions could be achieved by 2010, this would reduce future global warming by 0.2ºC at most. But it is argued that we have to start somewhere to avert disaster in the future.

8.5 Economic impact of mitigation

The cost of the current and proposed mitigation is considerable, but the government policy approach is that many of the measures have other benefits, such as encouraging lower use of energy resources or making buildings more resilient to extreme weather events. In January 2007, a £100 million Energy and Sustainability Capital Fund was announced for 2007-March 2009 to assist the National Health Service (NHS) in meeting the overarching target of 15% energy or 0.15 million tonnes carbon efficiency saving between 2000 and 2010. The energy performance of the NHS is improving, with over 70% meeting mandatory targets of 55-65 gigajoules/100m² – and in general, the UK is performing better than many other EU partners. UKCIP has published a standard methodology and guidelines to estimate the cost of climate change risks.

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**Box 8.2 Key provisions of the Draft Climate Change Bill (DEFRA, March 2007)**

- **Aim:** to reduce CO₂ emissions through domestic and international action by 60% by 2050 and 26-32% by 2020, against the 1990 base line
- **5-year carbon budget targets,** requiring secondary legislation to make binding limits on CO₂ emissions
- **Purchase of emissions reductions from overseas,** both to meet the carbon budget and to invest in low carbon technologies abroad (and the associated powers to introduce new trading schemes)
- **Establishing a Committee on Climate Change** as an independent statutory body to advise the Government, with an annual reporting requirement and a 5 yearly review of performance
- **Requirement for progress reports** on proposals and policies to integrate adaptation to climate change
Costs and benefits of any measure are inevitably location specific, depending on factors such as:

- **exposure to climate change effects** – e.g. areas experiencing greater warming, longer dry periods or more pronounced rises in sea level, or vulnerable groups e.g. in hospitals becoming more susceptible to heat stress
- **sensitivity to the effects** – e.g. heat stress has more serious health effects at extremes of age; some areas likely to be severely damaged by extreme weather such as intense rainfall
- **adaptive capacity** – feasibility and cost of installing e.g. air – conditioning units or to adjust to other climate hazards

It is now considered essential for socio-economic change to be incorporated in estimates of future climate-induced impacts – the impact pathway or cause and effect chain is shown diagrammatically in Figure 8.1 (Boyd & Hunt, 2006).

**Figure 8.1** Considering concurrent socio-economic change and climate change

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### 8.6 Energy supply industries (ESIs)

To impact on human-induced climate change, three major air pollutants need to be controlled: carbon dioxide (CO₂), oxides of nitrogen (Nox) and fine particles. The main measures in the UK involve the review of fuel use and policies to address market distortions and to reduce the use of conventional energy sources via:

- greater plant efficiency
- increased use of combined heat and power
- long-term investment in renewable energy sources
- waste strategy, including greater use of incineration to reduce demands on conventional power station fuels

Overall, the aim is to use 13% less mega tonnes of Carbon (MtC) by 2010, with associated reduction in the use of coal (less than 50 million tonnes to be used in 2010, compared with 70 million tonnes in 1997) and heavy oil. With further investment and associated higher cost, an additional 5% saving could be made in MtC. Emissions of sulphur dioxide (SO₂) and NOx will be controlled nationally to meet the UNECE Long Range Transboundary Air Pollution Convention (Department of Environment, 1996). Health benefits from these and associated measures have not yet been calculated.

### 8.7 Business: manufacturing and commercial sectors

The requirement to reduce carbon emissions will further shift energy use away from coal and oil and towards energy sources. Increased plant efficiency through implementation of Integrated Pollution Prevention and Control (IPPC) is part of the strategy to effect this change. The potential saving in MtC is 12% by 2010, with 10%
Because of growth in road transport, particularly private cars, CO₂ emissions rose by about 5% between 1990 and 2000

8.8 Transport

Because of growth in road transport, particularly private cars, CO₂ emissions rose by about 5% between 1990 and 2000. This is the only UK sector with rising levels, although EU countries taken together are doing better than the USA (Figure 8.2).

Figure 8.2 The countries with high emissions from fuel combustion (IEA, 2002)

The reduction strategy involves encouraging a switch from petrol/diesel to fuels such as gas and electricity. This is anticipated to reduce also emissions of regulated air pollutants, in particular NOx and fine particles. In 2006, the Air Quality Expert Group assessed that urban air quality goals will be more difficult to achieve in the medium term, because of the pressures of population and economic growth. The potential mitigation policies include:

- encouraging development of gas and electricity as fuels for transport
- lowering speed limits, hence fuel consumption
- traffic calming measures such as sleeping policemen (road humps)/roundabouts etc.
- promotion of public transport, walking and cycling

While the impact on climate change would be long-term, the health benefits of measures such as cleaner air and reducing speed would be almost immediate, for example in lowering the current excess of 3000 deaths from road accidents in the UK (Murlis and McCarthy, 2001). In the Health of Londoners’ Project (1999) it was calculated that a 10% shift from cars to cycling and walking could potentially save 100 deaths and 1000 hospital admissions each year.

8.9 Domestic sector

The domestic sector is responsible for around 14% of total CO₂ emissions (NETC, 1999) – even more if generation of electricity for this sector is included. This is therefore an important sector for policies on mitigating climate change. In the home, the main potential reduction in carbon emissions lies in energy conversion of heating and domestic appliances; and more efficient use of energy associated with improved home insulation. Changes in building regulations and wider use of community heating could also conserve energy. Potentially, such measures would represent a ‘win-win’ strategy, saving costs as well as reducing winter deaths and CO₂ emissions. However, progress in this sector depends upon a combination of factors, including:

- capital investment
- ability of hard pressed local authorities to comply with new legislation
...gas and electricity suppliers are now obliged to encourage or assist domestic customers to take up energy efficient measures, via the Energy Efficiency Commitment (EEC)

- the need for more energy efficient building regulations
- training issues and addressing engineering skills shortages
- reduction of the poverty that contributes to inefficient use of energy in the home

The relevant legislation includes HECA, 1995 (Box 8.3) and the Warm Homes and Energy Conservation Act, 2000. A Fuel Poverty Strategy was published in November 2001 (DTI, 2001), including the concept of ‘Warm Zones’ to coordinate activity on schemes to tackle fuel poverty. The consultation on the strategy produced various suggestions to improve the initiative, for example, with health impact assessments of effect on winter deaths or frequency of respiratory illness. In 2004, the Office of the Deputy Prime Minister (now Department for Communities and Local Government) published updated advice in ‘The Planning Response to Climate Change’, (www.communities.gov.uk/publications/planningandbuilding/planningresponse).

Some measures to address fuel poverty may increase MtC emissions, such as cold weather payments and winter heating allowances; this may make targets higher to achieve in the short-term and indicate the need for local partnerships and integrated campaigns that encourage the general strategy to reduce emissions. A European Directive on the energy performance of buildings (2002/91/EC) came into force in January 2006: it requires new buildings with a total floor area of over 1000 square metres to have renewable energy systems where feasible and energy performance certificates. On the smaller scale, the Home Improvement Packs introduced in 2007 focus particularly on energy performance in houses.

Box 8.3 The Home Energy Conservation Act 1995

This Act was introduced with the aim of increasing energy conservation measures by local authorities with housing responsibilities; it is also considered an important part of the UK climate change programme. HECA provisions include submission of reports to the Secretary of State on practicable, cost-efficient measures of energy conservation in residential accommodation. HECA fits into the wider sustainable development and Local Agenda 21 frameworks that emerged at the 1992 World Summit in Rio de Janeiro. Progress reports to the Department for the Environment, Food and Rural Affairs (DEFRA) suggests that an improvement in energy efficiency of nearly 30% is achievable by 2008, although so far it has been of the order of 2-3%. The Scottish Executive recently announced that HECA had reduced energy bills by an average of £26 for every household in Scotland. The Energy White Paper (Our Energy Future, 2003) builds on this with the stated aim of a cut in greenhouse gases by 60% by 2050.

In the Department of Health report on climate change, it was estimated that a 6% saving in MtC could result by 2010 on current policies, with an additional 7% saving from further planned measures. The government plans to increase funding for:

- Home Energy Efficiency Scheme (HEES)
- Energy Saving Trust
- Energy Efficiency Best Practice Programme
- Repairs to housing by local authorities

In addition, gas and electricity suppliers are now obliged to encourage or assist domestic customers to take up energy efficient measures, via the Energy Efficiency Commitment (EEC). These climate related policies could make a major impact on poverty and health, turning domestic energy efficiency issues from Cinderella areas to actively promoted schemes. With strong domestic policies, the unenviable high rate of cold-related deaths in the UK, compared with other partners in the European Union, would be expected to decline earlier than
the decline anticipated due to warmer winters later in this century. An increasing emphasis on conserving energy could also have a harmful effect on indoor air quality, for example with less ventilation in building design. As yet, the issue of increasingly warm summers and heat waves has not been addressed: a rise in the use of high energy demanding air cooling systems and fans could reduce the potential savings from insulation and alternative fuels.

8.10 Agriculture, forestry and land use

While fertilizers lead to significant emissions, agricultural soils and forests can also act as carbon sinks, sequestering carbon. A combination of changed agricultural policy and reforestation schemes would be expected to reduce MtC by about 4% by 2010. Fruit and vegetable production involves lower energy use than livestock and feeds: thus the climate mitigation measures could be combined with healthy eating policies to encourage diets higher in fruit and vegetables, with associated reduction in cardiovascular disease.

8.11 Public sector

The key measures in the public sector are energy efficiency and climate-friendly waste disposal. Currently, 85% of waste goes to landfill, producing about 40-50% of the natural emission of methane, one of the greenhouse gases (Murlis and McCarthy, 2001). In addition to schemes to recover landfill gases, a European Community Directive on landfill aims to reduce the amount of municipal solid waste diverted to landfill, for example by increased use of incineration, associated with heat and energy recovery. Conventional ESC fuels could be reduced by up to 5 million tonnes of coal equivalent by 2020 by such measures.

8.12 Secondary impacts of mitigation: balancing beneficial and potentially harmful effects

While many of the energy saving emission reducing measures could have direct health benefits (less winter related deaths, improved cardiovascular fitness, reduced air pollution and asthma, healthier diets), there are disadvantages to be considered (Table 8.1). Most of the mitigation measures require costly investment, which will need to be balanced against current environmental priorities. Many also require strong national government support, possibly augmented by changes in legislation and funding for local authorities. The long timescale of climate change is a major problem for environmental planning: for example, it is difficult to estimate when measures to prevent cold-related deaths, such as home insulation, will need to be overtaken or balanced by measures to prevent heat-related deaths. The climate change pressure is a welcome incentive to reduce the toll of preventable cold-related deaths in the UK. Deaths and illness associated with heat waves will be, in many ways, harder to prevent and the implications for building design are daunting. Health promotion is also challenging: perhaps the minimum approach should be to ensure that promotion of healthy diets and exercise always contains a mention of the benefits in also mitigating climate change. Health education would also need to cover the risks associated with wastewater recycling, if that became necessary to reduce costs of water treatment and sewage disposal.

8.13 Population and global warming

No discussion of mitigation can be considered complete without at least mentioning the relationship between the increasing population of the world and global warming. It has been claimed, for
Population forecasts have contributed to the political urgency of mitigation, such as by development of new and sustainable technologies and reduction in carbon emissions.

example by the Optimum Population Trust, that ignoring the exponential growth of population is to disregard the most obvious cause of the production of greenhouse gases. The world population (currently ~6.5 billion) is forecast to grow to 9.1 billion by 2050, while that of the UK (currently over 60 million) is projected to grow to nearly 71 million by 2074. Population forecasts have contributed to the political urgency of mitigation, such as by development of new and sustainable technologies and reduction in carbon emissions, although the Optimum Population Trust has calculated that even if the current world population stopped using fossil fuels and lived a western European lifestyle based entirely on renewable energy, it would still need, in total, 2.8 Earths – nearly two more planets – to support it. Further discussion of the role of over-population is outside the scope of this pack, but it highlights the greater priority that the environmental health profession should be giving to adaptation, considered in the next section.
Table 8.1  Mitigating factors for climate change: pros and cons

<table>
<thead>
<tr>
<th>Factor</th>
<th>Examples</th>
<th>Advantages for environmental health</th>
<th>Possible disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy conservation</td>
<td>1. Home insulation and building design</td>
<td>Less cold-related deaths; possibly more funding for repairs and insulation; improvement in housing conditions and poverty; cost effective for heating of public buildings. Alternative power sources e.g. solar power/wind power less damaging to health</td>
<td>Less ventilation to conserve energy could reduce indoor air quality. Long-term warmer winters may make measures for cooling during heat waves just as important: need for building design to address indoor environmental quality throughout the year. Energy savings from home insulation etc. could be offset by increased use of cooling systems/fans in warmer summers</td>
</tr>
<tr>
<td></td>
<td>2. Use of alternative power sources/fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy efficient waste disposal</td>
<td>1. Incineration rather than landfill</td>
<td>Heat and energy recovery; less methane problems from landfill; fits in with EU policies; building over former landfill sites would create housing</td>
<td>Large investment and planning permission needed to build and run more incinerators; incinerators unpopular with public</td>
</tr>
<tr>
<td></td>
<td>2. Waste water treatment and re-use</td>
<td>Conservation of water during droughts and to allow sharing with water-poor areas</td>
<td>Public accustomed to all water supply being of potable quality: risk of ingress/water-borne outbreaks</td>
</tr>
<tr>
<td>Increased efficiency of industrial plants</td>
<td>IPPC implementation</td>
<td>Increased control of emission of e.g. fine particles; energy savings from use of combined heat and power</td>
<td>Long and time consuming implementation – problem of monitoring, enforcement and costs</td>
</tr>
<tr>
<td>Energy efficient transport</td>
<td>Reduce use of private cars/re-design to use alternative fuels</td>
<td>Improvement in air quality</td>
<td>Very unpopular and possibly unenforceable unless public transport first greatly improved; dependent on national government initiatives</td>
</tr>
<tr>
<td>Using less transport</td>
<td>Walking to work</td>
<td>Energy savings; improvement in cardiovascular health</td>
<td>Requires continued programme of health promotion; need to provide safe paths for pedestrians; not feasible for many workers</td>
</tr>
<tr>
<td>Energy saving food production</td>
<td>Diets with high proportion fruits and vegetables rather than meat/poultry</td>
<td>Savings in agricultural sector (shift from livestock); cardiovascular/other systems would benefit</td>
<td>Requires continued programme of health promotion</td>
</tr>
</tbody>
</table>

Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change  57
9.0 Adapting to climate change

“Adaptation will be an essential part of the response to the threat of climate change”

Secretary of State for Environment, Food and Rural Affairs in foreword to UKCIP02 briefing report

Adaptation to the increased risk posed by climate change involves a combination of preparedness and plans for emergency response. The pragmatic approach involves ensuring that initiatives mainly addressed at non-climate aims (reducing inequalities, reducing the poverty gap) are seen also to make good sense in coping with climate change. Planning for floods and storms should be part of emergency planning, ensuring readiness for other types of emergencies, but to control the cost of planning and implementation, plans will need to be integrated, with shared training initiatives as well as flexibility in responses and greater emphasis on preparedness.

9.2 Long-term and emergency planning for floods and related storms

The expected increase in hurricanes – and floods – in the UK is possibly the most important message for environmental health interventions. After a period of being in the doldrums, following the nuclear planning exercises of the 1980s, emergency planning has re-emerged as an important area, with increasing acknowledgement of the importance of input by environmental health professionals and other specialists in public health. In addition to the emergency planning implications, there are several practical issues related to environmental health, including the pressure on professional staff from calls for help and advice (Box 9.1). These points are likely to be covered by existing flood emergency plans but with the increase anticipated from climate change, plans should be regularly updated. Exercises and real emergencies have demonstrated the importance of communications between agencies, as well as with the public and the media. The floods in 2007 increased the political urgency of adaptation: a pattern of more intense or more widespread flooding would be expected to undermine drainage systems and water supplies. Similarly the rapid response and dedication witnessed in the severe flooding in 2000 and 2007 in the UK has already stretched resources and community impatience is likely to increase if preventing flooding is perceived as a low government priority because of an apparent lack of planning and preparedness.

9.1 Adapting buildings and infrastructure to climate change

The building issue is controversial, because of the long time scale of the anticipated changes. For most of our lifetimes, winters are not going to be so warm that cold-related deaths become unlikely. The foreseeable need is to improve home insulation and encourage more efficient heating. Meanwhile, building design must also adapt to an overall warmer and wetter climate. For example, use of materials with high albedo (highly reflective and therefore cooling) on roads, parking lots and roofs would seem sensible. Community buildings such as hospitals, schools and primary care facilities will need to be able to withstand a higher frequency in flooding and severe storms. Because of the overall projected reduction in rainfall, particularly in southern England, water efficiency needs to be incorporated into national, regional and local planning policy for all new build and developments: this was also a recommendation of the 2006 London Climate Change Adaptation Strategy. The European Commission has launched a wide range of initiatives, including those to protect biodiversity (such as development of spatial plans and corridors to help species migrate).
Interventions to minimise health effects include, for example, reducing vulnerability to various hazards, or later in the event by increasing coping capacity, and seven main categories have been identified (Few et al., 2004):

i. Action in the home and community
ii. Health and Hygiene education
iii. Warning and Evacuation
iv. Disease surveillance and control
v. Health care provision
vi. Protection of health infrastructure
vii. Water and policy-related issues.

Responsibility for these interventions rests largely on local authorities and strategic health authorities, but involving households and community groups in the activities has important indirect health benefits. Active coping efforts, for example directed to clean up and recovery after floods, resulted in lower levels of psychological distress after floods in the Midwestern USA in 1993. Training in reducing household hazards, preparing emergency kits, evacuation plans and first aid has been incorporated into disaster plans in both the developed and developing world, e.g. ‘citizen disaster preparedness programs’ in California (Lichterman, 2000). Informal social support networks can also help to reduce the negative emotional impact of a flood; community bonds tend to be initially disrupted during a disaster, but if such networks have been fostered in advance, there is evidence that they greatly assist in recovery in the post-flood phase. Factors working against effective household and community responses include a low perception of the environmental risk (the ‘hurricanes hardly ever happen’ approach) and lack of effective coping mechanisms (e.g. lack of knowledge about how to cope with non-functioning toilets or difficult conditions for hygiene). Studies in England have reported a general lack of preparedness for flood events (Tapsell & Tunstall, 2000, 2001) and this was evident in media interviews with people suffering the 2007 floods, who expressed both surprise at the disaster and dissatisfaction with the information provided. Shock and disbelief may be an inevitable component of the response to disaster, which limits the ability of communities to provide self-help. Nevertheless, government responses, such as “this was an emergency nobody could have predicted” (Prime Minister, July 2007), need to show more awareness of the importance of community preparedness, as well as the funding required for training to increase local capacity to cope.

9.3 Health and hygiene advice after floods

Much of the work on hygiene advice has been conducted in developing countries, where the gravest risk of flood still applies. Advice in the UK has been greatly improved in the wake of the 2007 floods. Websites providing advice include:

**Box 9.1 Planning for the risks from floods**

- Providing adequate emergency advice: including phone lines
- Giving prompt and clear advice to the public; flood leaflets prepared in advance
- Mitigating flood damage to buildings, roads and power supplies – n.b. hospitals
- Identifying places of sanctuary for evacuated groups – and maintaining hygiene in crowded conditions (e.g. availability of toilets and washing facilities)
- Identifying likely drainage problems and instigating repair / preventive work
- Adequate stores of sandbags, skips for disposal of ruined property, road signs to replace those lost or damaged; budget for buckets, mops and cleaning materials; disposable cameras to record damage for insurance assessment
- Providing medical and social care for people involved in floods, including treating the effects of cold, psychological shock and displacement

Climate Change and its Health Implications: A summary report for environmental health practitioners on the health implications of climate change
The summer 2007 floods also raised concerns about sports playing fields and pitches that had been covered with flood water

1. Health Protection Agency, England and Wales: [www.hpa.org.uk](http://www.hpa.org.uk) Leaflets on health advice, cleaning up, coping with water shortages, water consumption, chemical and environmental hazards, flooded sports playing fields. Also a chemical event checklist for public health professionals, produced by the Chemical Hazards and Poisons Division (24 hour on call line 0870 606 6444). Information for people affected by flooding also on linked HPA site: [www.hpa.org.uk/webw/HPAweb/Page&HPAwebAutoListName/Page/1158934608011?p=1158934608011](http://www.hpa.org.uk/webw/HPAweb/Page&HPAwebAutoListName/Page/1158934608011?p=1158934608011)

2. NHS Direct, England and Wales: [www.nhsdirect.nhs.uk](http://www.nhsdirect.nhs.uk) (24 hour phone line 0845 4647)


4. Centers for Disease Control and Prevention, USA: [www.bt.cdc.gov/disasters/floods/index.asp](http://www.bt.cdc.gov/disasters/floods/index.asp) Advice on purification of drinking water, disinfection of wells, food safety, sanitation, personal hygiene, precautions on returning to homes, mosquito control, animal threats, chemicals and swift flowing water

Advice from these sources may need to be tailored to particular events or adapted for people with reading or comprehension problems (for example, the generally helpful “Information for people who have been affected by the flood” on the HPA website after the 2007 flooding used terms such as ‘overexertion’ and ‘hypothermia’ and contained no illustrations).

**Sports and outdoor play areas after floods**
The summer 2007 floods also raised concerns about sports playing fields and pitches that had been covered with flood water. Chemical risks were judged to be low, because of the substantial dilution effect from the large volume flood water. Microbiological risks, e.g. from faecal micro-organisms were assessed as low or little different from normal once the flood had subsided, as the normal soil on playing fields contains faecal organisms and tetanus spores. Also, additional micro-organisms deposited by the floods would be expected to decay rapidly during drying out, on exposure to sunlight. Advance preparation for the additional risks posed by floods and outdoor activities includes education (as ever) on hand washing, keeping tetanus immunisation up to date. Where specific chemical or other contamination is suspected, a risk assessment by the Local Authority, Health Protection Agency or Environment Agency is recommended before considering soil testing; the latter rarely provides useful additional information.
Table 9.1 Check list for advice and action on household health and hygiene during floods and storm disasters

<table>
<thead>
<tr>
<th>Subject</th>
<th>Aspects to be considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water safety</td>
<td>Sources, collection and storage</td>
</tr>
<tr>
<td>Excreta disposal</td>
<td>Hygienic places for defaecation</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>Solid waste and liquid waste</td>
</tr>
<tr>
<td>Personal hygiene</td>
<td>Water for washing/hand washing; protective clothing (gloves, waterproof boots, aprons)</td>
</tr>
<tr>
<td>Shelter</td>
<td>Evacuation areas/advice re: continued use of home/advice on return to home</td>
</tr>
<tr>
<td>Food safety</td>
<td>Food handling/preparation storage; baby feeds</td>
</tr>
<tr>
<td>Vector control</td>
<td>Advice re: insects/rodents</td>
</tr>
<tr>
<td>Education messages</td>
<td>TV, radio, websites; leaflets; public meetings; loudspeakers; household visits. Advance planning essential to ensure fast dissemination during and after flood or storm event</td>
</tr>
</tbody>
</table>

9.4 Adapting to windstorms

"...on the basis of evidence available to date, ... climate change will not significantly effect health via changes in windstorms." Department of Health, 2007

The latest Climate Change Scenarios indicate less effect on windstorms than in previous attempts to model this complex type of extreme weather event. But how well are we adapted to the present level of risk? While the severe storms and wind speeds over the next few decades are considered unlikely to cause significant damage to well structured buildings, there are several adaptation messages to lessen the impact of high winds in the UK (Box 9.2). The example of the January 2005 storm on the Isle of Man illustrates the range of disruption (Box 9.3). Probably the most important piece of health protective advice is to urge people to stay inside during storms, or to find a place of safety as soon as possible before the storm reaches its peak – and it may be necessary to explain what structures will be especially dangerous, such as mobile homes or buildings with wide roof spans. A four level ‘gust speed’ warning approach can be tailored to give specific advice when a storm is imminent, involving local media in giving prompt information to the public (Table 9.2). About 60% of the deaths from windstorms occur on the road or rail. Providing information on the likely effects of storms should include advice on vehicle instability, the need to keep streets clear of litter (even light litter can cause injury during a storm; heavy litter items become deadly missiles). Maintaining transport, power and communications are major
Old and neglected buildings will pose a considerable challenge in adaptations to the increased frequency of severe gales and higher wind speeds.
9.6 Water treatment and management/sanitation

The UK is unlikely to go seriously short of water, unlike many other parts of the world affected by climate change, but the climate change scenarios include the risk of longer periods of drought, particularly in the South East. On the global and European scale, the need for integrated water management between countries, regions and neighbouring areas has long been recognised: increases in seasonal temperatures and altered patterns of precipitation also have implications for water treatment. Environmental health officers have a key role in working with water undertakers to ensure that measures are in place to protect water quality, including that of private supplies, in the event of river floods and flash floods during torrential storms. Floods may damage generators, penetrate boreholes that do not have sufficient raised portals and power cuts may disable water treatment plants.

9.6 Adapting to heatwaves

Heatwave plans have been prepared to reduce heatwave mortality over the next decade. Building design improvements will aim to minimise the increased energy usage from fans and air conditioning. Thermal discomfort levels provide a means of setting thresholds for indoor temperatures (Table 9.4).

Traditional ways of coping with heat in Southern Europe include use of shade, fans and avoiding exercise at the hottest time of day – perhaps the siesta also will be considered for surviving hot weather in the UK. Obviously it is not just a matter of behavioural change as warmer weather has implications for workplace organisation and transport, such as ensuring adequate access to water. Health advice to the public may also include:

- Shutters and shades for windows, or thick curtains to reduce heating of the indoor environment.

<table>
<thead>
<tr>
<th>% of stock</th>
<th>pre 1919</th>
<th>1919-45</th>
<th>1945-64</th>
<th>post 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terraced houses</td>
<td>28.1</td>
<td>1.32</td>
<td>1.15</td>
<td>0.79</td>
</tr>
<tr>
<td>Semi-detached houses</td>
<td>26.7</td>
<td>1.54</td>
<td>1.32</td>
<td>0.93</td>
</tr>
<tr>
<td>Bungalow</td>
<td>23.5</td>
<td>2.0</td>
<td>1.72</td>
<td>1.21</td>
</tr>
<tr>
<td>Converted flats</td>
<td>6.9</td>
<td>1.01</td>
<td>1.13</td>
<td>0.83</td>
</tr>
<tr>
<td>Low-rise flats</td>
<td>12.7</td>
<td>0.81</td>
<td>0.7</td>
<td>0.48</td>
</tr>
<tr>
<td>High-rise flats</td>
<td>2.0</td>
<td>0.49</td>
<td>0.42</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Windows should be opened in early morning and shut if outdoor temperature rises above the inside.

Cooling measures include sprinkling water on the face and a cool bath or shower provides rapid cooling.

People on particular drugs such as phenothiazines, antidepressants and diuretics are more susceptible to heat stress and should be targeted with heat avoidance advice.

Avoid or cut down on alcohol as it decreases heat tolerance.

Meals with high carbohydrate and normal salt content should be encouraged, to counteract loss of salt and water in sweat and avoid dehydration.

In an emergency, e.g. someone collapsing from the effect of heat, immediate cooling at home is advised rather than waiting for hospital admission.

Air conditioning obviously helps, but there are concerns about its high energy consumption – similar concerns apply to ice in drinks and the habit learned from American films of standing in front of an open refrigerator to cool off. Advice on health in heatwaves should focus on the simple measures such as shade and hand fans – and not going out in the midday sun.

Assessment of heatwave impacts will play an important part in planning effective adaptation measures.

### 9.7 Protecting vulnerable groups

Evidence shows that the elderly and chronic sick are particularly vulnerable to the effects of extreme temperature episodes; also that heat-related morbidity is higher in the malnourished and other deprived groups. Adaptation plans must include specific measures to protect these groups, for example in providing practical assistance as well as advice during heatwaves. Visitors to an area may represent a vulnerable group during storms and floods and plans should include measures to give information and sanctuary to stranded people. The homeless are at increased risk from climate change, for obvious reasons. On the international scene, severe adverse weather events related to climate change (wide scale floods, drought, storms) would displace vulnerable populations. There is a strong possibility that migration patterns will be greatly influenced by the need to find more reliable sources of food, water and income.

### Table 9.4 Thermal discomfort temperatures and heat stress criteria

(adapted from table used for a case study on buildings (Hacker et al, 2005))

<table>
<thead>
<tr>
<th>Indoor environment</th>
<th>‘Warm’ temperature threshold</th>
<th>‘Hot’ temperature threshold</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>25°C</td>
<td>28°C</td>
<td>Building has overheated if it is over ‘hot’ temperature for more than 1% occupied hours. An indoor temperature above 35ºC represents a heat stress risk for healthy adults at 50% relative humidity.</td>
</tr>
<tr>
<td>Bedrooms in homes</td>
<td>21°C</td>
<td>25°C</td>
<td></td>
</tr>
</tbody>
</table>
Adaptation to the climate impact on food poisoning will involve further research into improved food storage, transport and preparation.

9.8 Reducing the impact of climate change on infectious disease

Food poisoning
Epidemiological research is urgently needed to examine the implications for food poisoning in more detail; this has practical implications for the data set collected on identified outbreaks and sporadic cases, for example in the need for data items related to climate factors (e.g. whether food stored/ served outdoors; heatwave link suspected in the investigation; clearer distinction between local and travel related cases, including travel within the UK). The climate connection for Campylobacter food poisoning is less clear, because growth is slow or insignificant below very hot ambient temperatures (30°C); reported cases of Campylobacter show a seasonal peak in early summer and further examination of Campylobacter from different countries that there could be value in analysing peaks at different latitudes of the UK and elsewhere in Europe, to investigate possible links with the food chain, water and a temperature lag effect. Adaptation to the climate impact on food poisoning will involve further research into improved food storage, transport and preparation: there is also a public health need to reinforce hygiene messages to adjust to the higher risks of a warmer climate, including basics such as hand washing, separation of raw and cooked food, covering food to reduce the risk of contamination by flies and when to discard food exposed to high ambient temperatures or outside buffets.

Vector borne disease

"Any malaria outbreaks in the UK ... are likely to be rare and on a small scale, affecting a small number of people." Rogers et al, DH 2007

For the next two or three decades, vector borne disease is unlikely to be a significant indigenous problem in the UK, but levels of reported cases of malaria may increase due to travel overseas. Surveillance systems should include clear distinction between travel acquired and home acquired cases of all vector borne infections to allow more precise monitoring of UK trends and early warning of, for example, re-emergence of P. vivax malaria. Any history of travel to a malaria endemic area should be clearly recorded; and any possible home-acquired cases are quickly reported to regional or national centres, particularly between June and September when survival of the parasites is more likely in the UK.

Two important priorities have been identified for the control of vectors in a changing climate (Rogers et al, 2001). Both are linked to surveillance: first, to ensure that GPs report ‘centrally’ any insect conditions, such as stings, rashes from caterpillars, tick and insect bites; secondly, to improve the surveillance of travel-related disease and ensure that GPs are on the alert to recognise disease symptoms and again to report ‘centrally’. In practice, this has implications for local surveillance and notification systems of infection and ‘central’ reporting would depend on the systems developed by Consultants in Communicable Disease Control and their Environmental Health colleagues. Planning for the need for enhanced surveillance will clearly have considerable resource implications. A system for identifying skin conditions possibly related to climate influences on vectors would be particularly difficult to establish. Similarly, an increase in house dust mites could exacerbate asthma and other allergic syndromes. In addition to giving advice on household hygiene for a warmer climate, there may be a need for local authorities to work with other agencies on improving reporting of possible climate-related conditions from nursing homes, hospitals and other institutions. Possibilities
include working with ‘spotter practices’ in primary care increased by climate change, as well as local or regional initiatives on enhanced surveillance.

The emphasis in the DH and other climate reports on the need for research, surveillance of ill health and monitoring of climate links is not surprising. In an evidence-based era, environmental health professionals will be expected to justify bids for more resources with quantified data. Currently the evidence comprises mainly ‘potential’ and qualitative estimates of the changes for the UK. The uncertainties involved in the climate change estimates of increased infection make enhanced surveillance one of the most important adaptation responses.

Other practical implications for water include controlling the spread of insect vectors (particularly mosquitoes) in small collections of water, such as water butts. As with mitigation measures, there would need to be a balance between conserving water resources and the risk of increasing vectorborne disease.

9.9 Adapting our surveillance systems

The search for more health evidence on the effects of climate change has revealed that the UK surveillance systems (and ours are better than most other countries) do not provide the detail of information required. This applies to infection but even more so to non-infectious disease and injuries. The problem is not so much that data does not exist, but that the information linked to cases (such as association with particular events) is not systematically recorded. Examples include:

i no systematic collation of travel related disease, whether from abroad or travel with the UK (the main problem is that a travel association may not be reported or recorded – post code studies are providing improved information but not on a routine basis. An example of an effective travel linked system is the European surveillance system for legionellosis (EWGLI)

ii further investigation of the time lag between higher ambient temperatures and subsequent infections requires a system that records date of onset accurately

iii other influences on food poisoning (buffets, barbecues, storage of food at warm temperatures) are well known but not systematically recorded

iv need for enhanced surveillance to investigate the dangers from vectorborne diseases – still many uncertainties about impact of different types of environment, spatial and temporal patterns e.g. surveillance system needs to provide information to match holiday destinations to disease risk

v no collation of injuries or drowning with sufficient information that could provide data on the effects of windstorms and floods (e.g. neither the Environment Agency nor DEFRA have formal criteria for a flood death)

vi information on mental health effects is dependent on epidemiological studies and there is no surveillance system to estimate overall levels attributable to extreme weather events

vii no system for active case searching of carbon monoxide deaths or illness (e.g. hospital admissions for treatment of CO poisoning)

viii no systematic surveillance for electrocution or vehicle accidents related to storms and floods

ix the incidence of heart or respiratory disease as influenced by climate is similarly hard to estimate without conducting a specific study
At present, the way forward for these surveillance gaps is for studies to be conducted by professionals in environmental health and public health after extreme weather events or to study seasonal alterations. Retrospective case control studies are an option (but costly) if clusters of particular conditions (e.g. skin cancers, mental illness, unusual infections) are identified following heatwaves and other extremes of weather. National surveillance improvements have often been shown to follow good practice examples in districts or regions: we are still a long way from the development of a minimum data base on climate-related health effects and influencing the funding and coordination required for this is a challenge for all working in environmental health.

9.10 Advantages (and limitations) of adaptation measures

Many of the measures to increase preparedness for climate change would have beneficial effects on other aspects of environmental health (Table 9.5). For example, amended building regulations for stronger roofs and ventilation, and advice on maintenance to prepare for storms, would improve the building stock. Campaigns to reduce the risk of flying debris in storms would address one of the perennial public complaints about litter and other rubbish on the streets and in public spaces. The limitations are chiefly the cost of preparedness and the pressure of other priorities for spending, given the long timescale and uncertainties about how quickly the climate change will impact on environmental health. Unintended consequences of adaptation need also to be considered: for example, the potential infection risks or pollution risks of recycling of grey water and production/use of biofuels. Protecting biodiversity, for example in maintaining natural wildlife areas or developing corridors for migration, may exacerbate environmental health issues such as fox and rodent control. While clear priorities have been identified for the ‘high confidence’ climate impacts, such as heatwaves and infection related to increased temperature, preparation for floods and windstorms should not wait for further evidence of increased frequency of these events.
<table>
<thead>
<tr>
<th>Factor</th>
<th>Examples</th>
<th>Advantages for environmental health</th>
<th>Possible disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing the urban heat island effect</td>
<td>Improved building insulation; improved building codes e.g. e.g. high albedo materials for roofs</td>
<td>Better quality housing and improved indoor environment</td>
<td>Higher costs for urban authorities and urban residents – need for government to assist</td>
</tr>
<tr>
<td>Cooling during heatwaves</td>
<td>Building design for warmer climate; health advice during heatwaves</td>
<td>Less heat-related deaths; work efficiency through more comfortable environments</td>
<td>Energy savings from home insulation etc. could be offset by increased use of cooling systems/fans in warmer summers; cost and difficulty of rapid response in health promotion campaigns</td>
</tr>
<tr>
<td>Preventing effects of major floods</td>
<td>1. Cease building on flood plains and put in measures to protect existing developments</td>
<td>Reduction in damage to houses and effects on health from flooding/storms</td>
<td>Prohibitive cost of re-housing communities in existing high risk areas; flood barriers etc. also costly, probable need for government investment for buildings, roads and sewers</td>
</tr>
<tr>
<td></td>
<td>2. Improving building codes</td>
<td>Road improvements can radically reduce the duration of flooding and hence its health and environmental effects</td>
<td>Plans need to include medium and long-term effects – e.g. depression</td>
</tr>
<tr>
<td></td>
<td>3. Design roads to act as drains in high risk areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preventing effects of minor floods/</td>
<td>1. Improve sewerage system to ensure protection from overflows/ingress during floods</td>
<td>Reduced risk of contaminated drinking water</td>
<td>Costly; large differences between urban and rural areas would require plans to be tailored to specific community needs – need for grants to improve private water supplies/homes without mains sewerage. Implications for water rate from adaptation measures needed for water sources – knock-on effect on poverty/cost of living</td>
</tr>
<tr>
<td>torrential storms</td>
<td>2. Protect surface and groundwater sources from pollution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preventing effects of severe storms</td>
<td>1. Improve building design e.g. roofs/fencing/drainage (long term: change in building regulations for roofs)</td>
<td>Prevent damage to health and environment due to increased frequency of severe storms; boost for emergency planning – could benefit other areas and general preparedness for adverse events</td>
<td>Feasible for new buildings but costly to convert/upgrade existing buildings; need for investment in staff and resources in emergency planning – public criticism if storms infrequent! Difficult to persuade people not to drive or go out in early stages of storm, too late once the peak is reached</td>
</tr>
<tr>
<td></td>
<td>2. Public health advice on avoiding injury i.e. to stay at home</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Litter campaigns to reduce debris flying about</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preventing infection</td>
<td>Ensuring cool transport/storage of food/food products; health education</td>
<td>Reduction in food poisoning; improved hygiene e.g. hand washing</td>
<td>Need to incorporate climate change awareness in HACCP training; hard to influence behaviour; health education needs to be timed to coincide with adverse weather events/heatwaves etc.</td>
</tr>
<tr>
<td>Conserving water supplies</td>
<td>Shift to less water intensive crops/livestock; Wastewater treatment and reuse</td>
<td>Environmental benefits</td>
<td>Hygiene issues – water re-use, less washing; impact on home grown health foods such as fruit and vegetables</td>
</tr>
<tr>
<td>Public ability to cope with adverse</td>
<td>Regular public health information programmes; provision for non-electronic information in case of power failure</td>
<td>Encouraging adaptive behaviour and reducing injuries/disease</td>
<td>Costly, risk of ‘overkill’; need for accurate weather information in time to release information posters/leaflets/website advice etc.</td>
</tr>
<tr>
<td>weather events</td>
<td></td>
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</tbody>
</table>
10.0 Summary and conclusion

“...stabilising global concentrations at today’s levels would require cuts in emissions of 60-70% now, and even then temperature would still rise by 0.7ºC” (DETR, 2000, report by ERM) – more recent reports are still gloomy about both meeting targets and the impact on temperature in the foreseeable future.

“The state of the weather is almost the first subject about which people talk when they meet, and it is not surprising that a matter of such importance to comfort, health, prosperity, and even life itself, should form the usual text and starting-point for the conversation of daily life.” Richard Inwards, ‘Weather Lore’, 1893

The evidence shows that further global warming is inevitable, with several potential health effects, and that the practical measures for the short-term are those of adaptation. The reason why mitigation appears to be the predominant pre-occupation of government departments is probably that targets for reducing emissions are easier to set than those for the wider range of measures required for adapting to climate change. Until the changes become more evident (and the UKCIP02 scenarios are generally reassuring regarding changes in the 30 year ‘time-slice’) it seems likely that people will continue to debate what is to be done about climate change – and of course to go on talking about the weather.

10.1 Assessment at a time of uncertainty

Assessing the impact of climate change is complicated by:

1. the nature, scale and imprecision of estimates of climate change risk
   • no precise data are available to allow short-term planning for risks

2. the uncertainty regarding estimates of particular diseases likely to be affected by climate change
   • surveillance systems have not yet been adapted to measure the contribution of climate change effects and in some cases, such as asthma, the causes are not sufficiently established to be able measure the possible influence of ozone depletion.

   The medium to long-term follow-up of adverse climate events such as floods is also costly and time-consuming

3. the relative priority of active steps that can be taken to adapt to unacceptable risks
   • the DH expert review recommended emphasis on planning for windstorms and floods

4. the relative importance of some climate effects in particular areas of the UK, e.g. coastal areas, those with a high density of property on flood plains and those likely to suffer from water shortages

5. the high cost of some of the adaptation measures, for example on building construction and maintenance
   • the cost of meeting climate sensitive building regulations and standards has been estimated to be between £2.2-15.5 billion for the residential sector and £1.5-10.4 billion for the commercial sector (DETR, 2000)

10.2 Summary of climate change and its health effects

a) Climate change
   • Average temperatures likely to rise by 2°C by 2080 (low emissions scenario) or 3.5°C by 2080 for the high emissions scenario: by the 2080s, parts of the southeast may be up to 5ºC in summer. Heatwaves/very hot summers will increase – occurring in one year in five by 2050s (medium-high scenario)
   • Extreme sea levels will be experienced more frequently: some east coast areas could experience extreme levels 10-20 times more often. The relative sea level will continue to rise around most of the UK shoreline
   • Flooding to increase (precipitation to decrease in southern England, increase in northern England, wide variation and not yet possible to quantify)
• There is uncertainty about whether windstorms/severe gales will increase: possibility of more severe/stronger winds in southern and central Britain and also of a trend to more winds due to natural climate variation, rather than to global warming
• Average growing season to increase (already 10 days longer than 1960s)

b) Health effects
• increase in infectious diseases (e.g. 4.5% increase in food poisoning by 2020s, vectorborne disease such as malaria (possibility of P. vivax malaria in southeast England by 2020), travel related and water related disease, increase in fleas, cockroaches etc)
• annual excess heat-related deaths to increase to 2800 by 2050s
• annual excess cold-related deaths to decrease from 80,000 to 60,000 by 2050
• increase in diseases due to greater exposure to ultraviolet radiation (skin cancers/cataracts), related to more outdoor exposure in warmer climate
• increase in allergies/exacerbation of asthma
• increase in mental ill health e.g. due to trauma of floods and storms
• if the current trend in storms continues there could be increased accidents due to windstorms, also associated with increase of vulnerable housing stock due to insufficient wind protection
• overall decrease in diseases/premature mortality associated with air pollution (about 50% during the climate change expected this century), but possible risk of ozone episodes during hot summers

10.3 Early actions needed to protect environmental health
This report has attempted to identify some of the early actions that need to be taken, including the relatively low cost of preparing plans and information for floods, heat waves, droughts and windstorms (Table 10.1).

<table>
<thead>
<tr>
<th>Flooding</th>
<th>Heatwaves</th>
<th>Windstorms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk assessment</strong></td>
<td>Improve flood risk identification</td>
<td>Monitor climate warnings/prepare for prolonged heatwaves</td>
</tr>
<tr>
<td><strong>Public information</strong></td>
<td>Raise awareness of practical steps to minimise exposure to flood damage risks</td>
<td>Distribute information on reducing health risks, including food poisoning</td>
</tr>
<tr>
<td><strong>Planning/building implications</strong></td>
<td>Use planning and insurance to help to discourage future development in high flood risk areas</td>
<td>Incorporate climate headroom and energy efficiency measures into new/revised building standards and guidance</td>
</tr>
<tr>
<td><strong>Liaison</strong></td>
<td>Local partnerships/integrated planning</td>
<td>Liaison with health service providers</td>
</tr>
</tbody>
</table>

Table 10.1 Summary of early actions to adapt to climate change
While the UK effects of climate change are not likely to be severe in the short, or even the longer term, the globalisation of resources means that the UK will be inevitably affected by more severe climate trends elsewhere.

Raising awareness about the need for adaptation by the general public and by businesses is an important measure, as is integrating climate adaptation responses into existing policies and programmes, particularly where these relate to water resources, buildings and infrastructure. Planning tools such as strategic environmental assessment and health impact assessment are one way of ensuring that climate effects are integrated into the process. While the cost of adapting to climate change may seem high, given other priorities, the issue of the cost of ‘doing nothing’ must be considered. For example, disruption to businesses, energy supplies, other services and damage to fixed assets are often very high in a severe weather event – and we know that floods and storm intensity are going to increase.

Experience suggests that we do not plan very effectively for infrequent events, but the now evident increased risk of flooding has produced some excellent plans and responses. The Improvement and Development Agency is collecting examples of good practice (www.idea.gov.uk) and there is a need for case studies on effects and adaptation – these could be incorporated into future reviews of this document and related work on climate change. Suggestions on possible topics for case studies include:

- trials of surveillance for specific problems such as carbon monoxide poisoning, travel related infections within the UK and imported infection problems that may be climate related
- Surveys of surface drainage re: flood risk and implication of increasing urban development
- Studies of community response to health advice re: heatwaves, outdoor eating and food poisoning, floods and storms
- Local studies of eco-systems, eco-technology re: sustainability to the impact of climate change (e.g. use of recycled water)

While the UK effects of climate change are not likely to be severe in the short, or even the longer term, the globalisation of resources means that the UK will be inevitably affected by more severe climate trends elsewhere. Some of the global effects, such as potential increased migration to the UK because of climate problems elsewhere, or changes in food availability, highlight the need to include climate into plans for sustainable development and services.
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Adaptation guidance Local Communities and Climate Change – How prepared are you? Helps councils to understand the impact on council services of the changing climate and how services need to adapt Local Authority Carbon Management Programme www.carbontrust.co.uk/publications/publicationdetail?productid=1PAC047
Advice and support for local government – Environmental Management Systems (EMS)  

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Community Leadership and Climate Change Guidance for Local Authorities guidance on a range of opportunities for councils to develop their response to climate change  
www.idea-knowledge.gov.uk/idk/aio/396534 also refer to Annex F of the Local Government White Paper to be found at  
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**Wind storms**

### Appendix  List of tables, boxes and figures

<table>
<thead>
<tr>
<th>Title</th>
<th>Section / Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box 1.1  Climate change – definition</td>
<td>1 / p.6</td>
</tr>
<tr>
<td>Box 1.2  Climate change and the El Niño Southern Oscillation</td>
<td>1 / p.8</td>
</tr>
<tr>
<td>Box 2.1  The medium-high scenario for the UK</td>
<td>2 / p.9</td>
</tr>
<tr>
<td>Figure 2.1  Changes in mean annual temperature (low, medium-low, medium-high and high climate change scenarios (UKCIP98))</td>
<td>2 / p.10</td>
</tr>
<tr>
<td>Figure 2.2  Mean temperature changes for 2020s, 2050s and 2080s (UKCIP02)</td>
<td>2 / p.10</td>
</tr>
<tr>
<td>Figure 2.3  Mean precipitation change for 2020s, 2050s and 2080s (UKCIP02)</td>
<td>2 / p.11</td>
</tr>
<tr>
<td>Figure 2.4  Diurnal temperature change (low, medium-low, medium-high and high emissions in the 2020s (UKCIP02))</td>
<td>2 / p.11</td>
</tr>
<tr>
<td>Table 2.1  High confidence statements re: direction of climate change (UKCIP02)</td>
<td>2 / p.13</td>
</tr>
<tr>
<td>Figure 2.5  Summer soil moisture projections for 2050s (UKCIP02)</td>
<td>2 / p.13</td>
</tr>
<tr>
<td>Figure 3.1  Global air temperature in UK time series (Climatic Research Unit and UK Met. Office)</td>
<td>3 / p.14</td>
</tr>
<tr>
<td>Figure 3.2 (a-l)  Changes in annual average daily temperature by region (UKCIP02)</td>
<td>3 / p.15-18</td>
</tr>
<tr>
<td>Figure 3.3  Precipitation (rainfall) 18th century to present (England and Wales regional averages)</td>
<td>3 / p.18</td>
</tr>
<tr>
<td>Figure 3.4  Number of days each winter following 5 days of “very wet” weather and hence flooding risk (CRU)</td>
<td>3 / p.19</td>
</tr>
<tr>
<td>Figure 3.5  Contribution to each winter’s total precipitation made from “heavy” precipitation days (CRU)</td>
<td>3 / p.19</td>
</tr>
<tr>
<td>Figure 3.6 (a-l)  Percentage change in summer precipitation (UKCIP02)</td>
<td>3 / p.19-22</td>
</tr>
<tr>
<td>Figure 3.7 (a-l)  Percentage change by region in winter precipitation (UKCIP02)</td>
<td>3 / p.22-25</td>
</tr>
<tr>
<td>Figure 3.8  Water abstracted for irrigation in England and Wales, 1971-1998 (CRU)</td>
<td>3 / p.27</td>
</tr>
<tr>
<td>Table 3.1  Responses to climate shifts</td>
<td>3 / p.28</td>
</tr>
<tr>
<td>Table 3.2  Summary of estimated future climate change for UK (UKCIP02)</td>
<td>3 / p.29</td>
</tr>
<tr>
<td>Table 4.1  The three key features of health impact assessment in climate change</td>
<td>4 / p.31</td>
</tr>
<tr>
<td>Figure 4.1  Change in cloud cover, projection for 2020s (UKCIP02)</td>
<td>4 / p.34</td>
</tr>
<tr>
<td>Figure 4.2  Cloud change projection for 2050s (UKCIP02)</td>
<td>4 / p.34</td>
</tr>
<tr>
<td>Table 4.2  Global health impact of climate change</td>
<td>4 / p.35</td>
</tr>
<tr>
<td>Title</td>
<td>Section / Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Table 5.1 Causes of heat related mortality</td>
<td>5 / p.36</td>
</tr>
<tr>
<td>Box 5.1 Temperature increases and food poisoning</td>
<td>5 / p.38</td>
</tr>
<tr>
<td>Box 5.2 Insects and other vectors that may increase in a warmer UK</td>
<td>5 / p.40</td>
</tr>
<tr>
<td>Table 6.1 Summary of potential health risks from floods</td>
<td>6 / p.43</td>
</tr>
<tr>
<td>Box 7.1 The effects of high wind speed</td>
<td>7 / p.46</td>
</tr>
<tr>
<td>Figure 7.1 Projected windspeed changes for 2020s (UKCIP02)</td>
<td>7 / p.47</td>
</tr>
<tr>
<td>Figure 7.2 Projected windspeed changes for 2050s (UKCIP02)</td>
<td>7 / p.47</td>
</tr>
<tr>
<td>Box 8.1 Regulations/relevant air legislation on mitigating climate change</td>
<td>8 / p.49-50</td>
</tr>
<tr>
<td>Box 8.2 Key provisions of the Draft Climate Change Bill (DEFRA, March 2007)</td>
<td>8 / p.51</td>
</tr>
<tr>
<td>Figure 8.1 Considering concurrent socio-economic change and climate change</td>
<td>8 / p.52</td>
</tr>
<tr>
<td>Figure 8.2 The countries with high emissions from fuel combustion (IEA, 2002)</td>
<td>8 / p.53</td>
</tr>
<tr>
<td>Box 8.3 The Home Energy Conservation Act 1995</td>
<td>8 / p.54</td>
</tr>
<tr>
<td>Table 8.1 Mitigating factors for climate change: pros and cons</td>
<td>8 / p.57</td>
</tr>
<tr>
<td>Box 9.1 Planning for the risks from floods</td>
<td>9 / p.59</td>
</tr>
<tr>
<td>Table 9.1 Check list for advice and action on household health and hygiene during floods and storm disasters</td>
<td>9 / p.61</td>
</tr>
<tr>
<td>Table 9.2 Reducing the risk of exposure to gales – advice tailored to gust speeds</td>
<td>9 / p.62</td>
</tr>
<tr>
<td>Box 9.2 Adaptation measures for windstorms</td>
<td>9 / p.62</td>
</tr>
<tr>
<td>Box 9.3 Impact of the windstorm on Isle of Man, 2005</td>
<td>9 / p.62</td>
</tr>
<tr>
<td>Table 9.3 Proposed composite vulnerability indices for UK building stock (DH, 2001)</td>
<td>9 / p.63</td>
</tr>
<tr>
<td>Table 9.4 Thermal discomfort temperatures and heat stress criteria</td>
<td>9 / p.64</td>
</tr>
<tr>
<td>Table 9.5 Adaptation factors for climate change: pros and cons</td>
<td>9 / p.68</td>
</tr>
<tr>
<td>Table 10.1 Summary of early actions to adapt to climate change</td>
<td>10 / p.70</td>
</tr>
</tbody>
</table>