Action in Partnership

Third Ministerial Conference
on Environment and Health
London 1999

World Health Organization
Regional Office for Europe

Third Ministerial Conference on Environment and Health
London, 16–19 June 1999

9 April 1999
ORIGINAL: ENGLISH

Background document

EARLY HUMAN HEALTH EFFECTS OF CLIMATE CHANGE AND STRATOSPHERIC OZONE DEPLETION IN EUROPE

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About this book

The agenda for action on environment and health in Europe for the beginning of the next century will be defined at the Third Ministerial Conference on Environment and Health in London, June 1999. This background document has been prepared by the Working Group on the Early Human Health Impacts of Climate Change. The Working Group was convened by the WHO, European Centre for Environment and Health, Rome Division, at the request of the European Environment and Health Committee (EEHC). The working group consisted of representatives of national governments, international organizations, the European Commission, and academics. The areas of expertise represented included biology, climatology, epidemiology, geology, infectious disease, mathematics and public health.

A separate policy document contains the recommendations of the Working Group for actions to reduce or prevent the impacts of climate change on the health of populations in Europe (Appendix A). These recommendations were agreed upon at two meetings of the Working Group in May and October 1998 (WHO-ECEH, 1998a,b). Members of the Working Group on the Early Human Health Impacts of Climate Change are listed in Appendix B.

The evidence comprising the substance of this document is based on predominantly reductionist science. Consequently, any holistic view of interactions, and of synergistic or deleterious effects across species or their component parts, and across disciplinary lines would be minimal. Further, what is included here is based only on that which has been reported in the accessible literature. It is important to recognise that many questions relating to climate change and population health remain unanswered and have yet to be investigated scientifically. Publication bias could have affected the literature to reflect only the results from positive studies. The focus in future should be on more holistic approaches for understanding the impact of problems identified to date.

The authors would like to offer special thanks to the individuals who supplied text or data, reviewed early drafts, or provided assistance in other ways, thereby contributing much to the monographs present substance. The authors' special thanks to:

Simon Hales (Wellington School of Medicine, New Zealand), Mike Hulme (Climatic Research Unit, University of East Anglia, UK), Marco Jermini (WHO European Centre for Environment and Health-Rome division), Katrin Kuhn (London School of Hygiene and Tropical Medicine, UK), Tim Lack (Water Research Centre, UK), Matthew Livermore (University College London, UK), Kathy Pond (WHO European Centre for Environment and Health-Rome division), Francesca Racioppi (WHO European Centre for Environment and Health-Rome division), Gerreth Rees (Director Robens Centre for Public and Environmental Health, UK), Geoffrey Tiernay (DG XI, European Commission), Alistair Woodward (Department of Public Health, Wellington School of Medicine, New Zealand)

Acronym list

ACACIA	A Concerted Action Towards a Comprehensive Impacts and Adaptation Assessment for the European Union
APHEA	Air Pollution and Health, a European Approach
CCIRG	Climate Change Impacts Review Group, UK
CDSC	Communicable Disease Surveillance Centre, UK
CET	Central England Temperature
CFC	Chloroflurocarbon
CGCP	Canadian Global Change Programme, Canada
CL	Cutaneous leishmaniasis
EC	European Commission
ECEH	European Centre for Environment and Health (WHO)
ECHO	European Community Humanitarian Office (EC)
ECSN	European Climate Support Network
EEA	European Environment Agency
EEHC	European Environment and Health Committee
EMC	Division of Emerging and other Communicable Diseases (WHO, Geneva)
ENEA	Ente per le Nuove tecnologie, l'Energia e l'Ambiente
ENRICH	European Network for Research on Global Change (European Union)
ENSO	El Niño Southern Oscillation
ESF	European Science Foundation
ETAN	European Technology Assessment Network (European Commission)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAW	Global Atmosphere Watch (WMO)
GCM	General circulation models
GCOS	Global Climate Observing System
GEENET	Global Environmental Epidemiology Network (WHO)
GEMS	Global Environment Monitoring System (WHO/UNEP)
GHG	Greenhouse gas
GIS	Geographic Information Systems
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
HED	Commission on health and development
HEGIS	Health and Environment Geographic Information System
HFRS	Haemorrhagic fever with renal syndrome
IACCA	UN Inter Agency Committee on the Climate Agenda
ICSU	International Council of Scientific Unions
IGBP	International Geosphere–Biosphere Programme
IGFA	International Group of Funding Agencies
IGU	International Geographic Union
IHDP	International Human Dimensions Programme on Global Environmental Change
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPCC	Intergovernmental Panel on Climate Change
IPTS	Institute for Prospective Technological Studies-Joint Research Centre, (EC)
MRC	Medical Research Council, UK
NAO	North Atlantic Oscilllation
NAST	National assessment synthesis team, USA
NERC	Natural Environment Research Council, UK
NHMRC	National health and Medical Research Council, Australia
NRP	National Research Programme, The Netherlands
TBE	Tick-borne encephalitis
UNCED	United Nations Conference on Environment and Development (Rio Summit)

UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environment Protection Agency
USGRCP	United States Global Change Research Programme
UVR	Ultraviolet radiation
WAIS	West Antarctic ice sheet
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)
ZVL	Zoonotic visceral leishmaniasis

Executive summary

Human environmental impacts now include unprecedented changes at global level in the atmosphere and the stratosphere. Climatologists project that greenhouse gas accumulation in the lower atmosphere will change the world's climate and have apparently already begun to do so. Depletion of stratospheric ozone has occurred in recent decades. The relationship between the two phenomena is complex and new knowledge is emerging. Authoritative international reviews have concluded that these global environmental changes will affect human health, mostly in adverse ways. At global level, some of the ongoing changes in patterns of human disease are compatible with the advent of climate change. However, further research is needed to clarify these and future relationships.

It is anticipated that climate change and stratospheric ozone depletion will have a range of health impacts. Some will result from direct effects (e.g heatwave-related deaths and skin cancer induced by ultraviolet radiation); others will result from disturbances to complex physical and ecological processes (e.g.changes in patterns of infectious disease, drinking-water supplies and agricultural yields). Some health effects may become evident within the coming decade; others would take longer. Furthermore, failure to reduce fossil fuel combustion (as the principal means of reducing greenhouse gas emissions) will result directly in a continuing (and increasing) avoidable burden of mortality and disease from exposure to local air pollution.

There is a need to consider how these global change processes will affect the health of European populations, how to minimize adverse health impacts, how to improve monitoring and research, and how to facilitate all such actions through Europe-wide coordination, sharing of information, and cooperation in wider international efforts.

The 1992 United Nations Conference on Environment and Development (UNCED) recognized, in Agenda 21, that the unavoidable uncertainties attached to forecasting the potentially serious impacts of global environmental change do not justify a wait-and-see approach. Rather, in such circumstances there is a strong case for prudent and precautionary action. This "precautionary principle" is manifestly relevant to global climate change and stratospheric ozone depletion because of the possible occurrence of irreversible changes in the world's environment and climate systems and because of the potentially serious nature of the associated health outcomes.

The aim of this document is to review the scientific evidence and policy implications for the potential impacts of climate change on human health. The first chapter describes the initiatives carried out on climate change and human health at both global and European levels. The second chapter gives an overview of climate change and scenarios for the next century for Europe. The third chapter addresses the health impacts of climate change. Particular attention is given to potential impacts on thermal stress and vector-borne diseases. The fourth chapter reviews the health impacts of stratospheric ozone depletion. Particular attention is given to the effects of ultraviolet radiation on the immune system. Climate change effects on human health may already be occurring, therefore, a chapter on the "early" health effects of climate change has been included. "Early" effects in this context are defined as those effects, which are anticipated to occur within the next 10-30 years. The last chapters describe those actions necessary to reduce the health impacts of climate change. Actions include the benefits on population health of policies to reduce climate change (mitigation) and from preventive actions to reduce potential health impacts of climate change (adaptation).

1. Introduction

The aggregate environmental impact of humankind has begun to change some of Earth's great biophysical systems. Such human-induced systemic environmental change is unprecedented in human history. In particular, humans are altering the composition of the atmosphere. Changes in the lower atmosphere may cause long-term global climate change. Changes in the stratosphere increase the amount of harmful ultraviolet irradiation at Earth's surface.

The global environmental changes that are now taking place have common origins in the scale and type of both on-going and escalating human economic activities. Population growth, the spread of industrialisation and modern transport systems, increased consumerism, and the emergence of a global world economy are affecting the environment in ways we might not have thought possible several decades ago. Concerted, co-ordinated action will be required to adapt to and mitigate the environmental and health consequences arising from these activities.

Fundamental connections exist between the natural world and the human economy. There can be no sustained economic development without an intact natural environment. In turn, human well-being and health depend fundamentally upon those same two entities: the "goods and services" that provide the world's life-support systems. Hence, there is a need to assess the potential health consequences of global environmental changes. However, the linkages between these global change processes, between their joint impacts, and the unknown future course of human socio-technical development makes the estimation of such impacts a complex and uncertain enterprise.

This report addresses the impacts of both climate change and stratospheric ozone depletion on health. Both processes are linked by virtue of various chemical and physical relationships in the atmosphere and these provide sufficient reason for considering stratospheric ozone depletion when making an overall assessment of the health effects of climate change (see Box 1).

Nevertheless, the essential difference between greenhouse gas accumulation and stratospheric ozone depletion should be borne in mind. Greenhouse gas accumulation increases the effect of radiative forcing on climate, while destruction of stratospheric ozone by chemicals including chlorine radicals leads to increased ultraviolet radiation (UVR) at ground level. These two distinct phenomena are members of a wider-ranging family of global environmental change now emerging in our "overloaded" world.

Box 1: The relationship between climate change and stratospheric ozone depletion

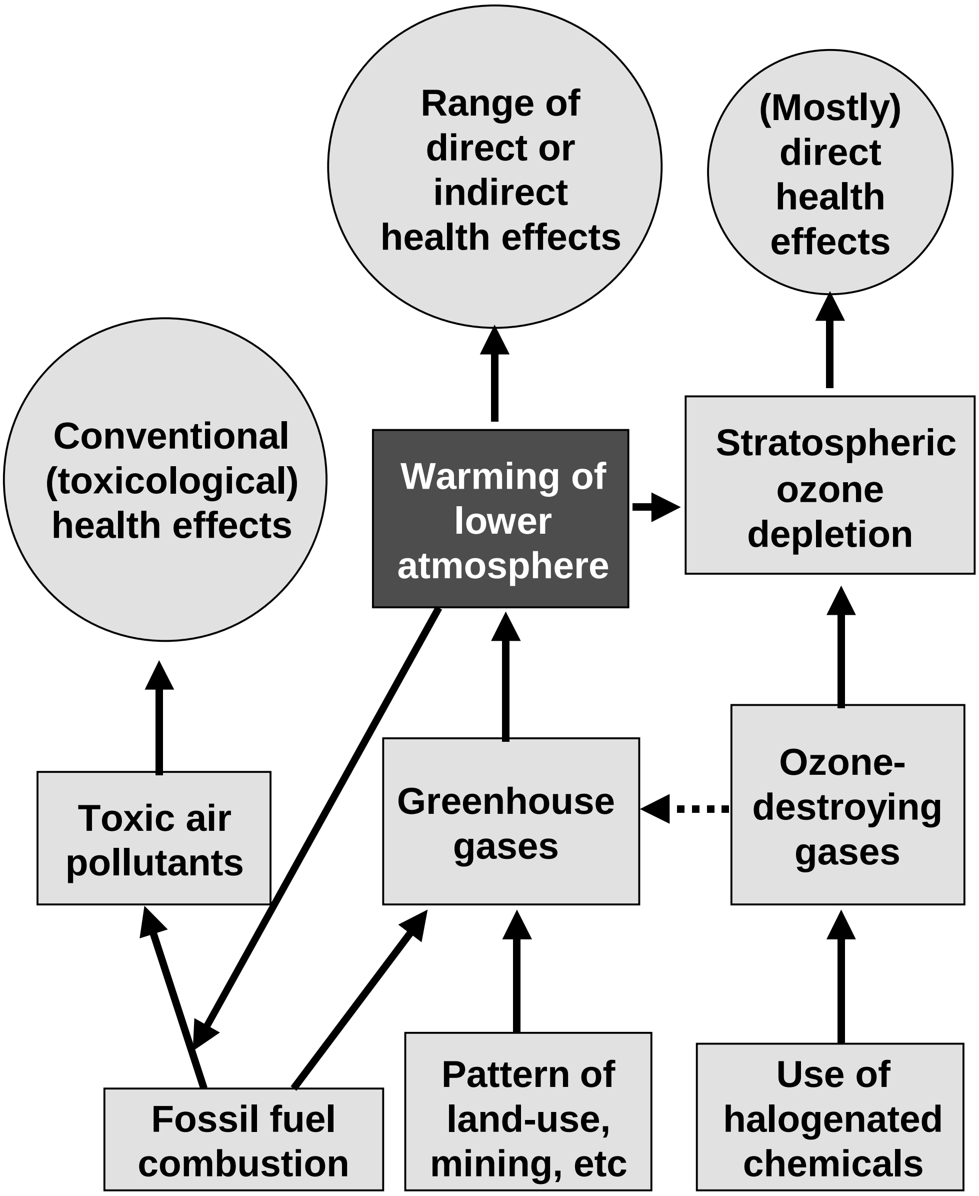
Climate and weather are often thought to be a product of the *lower* atmosphere — that is, the troposphere. Hence, to include a section about the depletion of ozone in the stratosphere, or middle atmosphere, in a report about global climate change may seem inappropriate. Stratospheric ozone destruction is an essentially separate process from greenhouse gas (GHG) accumulation in the lower atmosphere but there are several links between the two processes (Rind and Lacis, 1993; WMO et al., 1994).

Several of the GHGs, especially chloroflurocarbons (CFCs), produce radicals that also destroy ozone. Ozone is itself a GHG. Ozone depletion has caused the stratosphere to cool by between 0.6°C and 0.8°C during the past two decades. It is estimated that ozone depletion in the lower stratosphere may have offset 15–20% of the positive radiative forcing that has occurred in recent decades (Bojkov, 1995). (Levels of tropospheric ozone have nevertheless increased.)

Tropospheric warming apparently induces stratospheric cooling which exacerbates ozone destruction (Shindell *et al.*, 1998).

Further, in a warmer world, patterns of personal exposure to harmful solar radiation (e.g. sun-bathing in temperate climates) are likely to change. Ground-level UV radiation, while primarily determined by the extent of stratospheric UV absorption, is reduced by clouds and air pollution in the troposphere. As both are temperature-dependent, climate change may affect ground-level UV radiation.

Figure 1: Interaction among climate change, stratospheric ozone depletion and air pollution



Source: McMichael, personal communication. WHO-ECEH, 1998a

1.1 Initiatives on climate change and human health

Growing awareness of climate change has stimulated several assessments of its likely impacts on human population health. In particular, the United Nation's Intergovernmental Panel on Climate Change (IPCC) has comprehensively reviewed the scientific literature on this topic in the Second Assessment Report (IPCC, 1996a WGII Chapter 18; McMichael *et al.*, 1996a). The IPCC Regional Assessment also addressed health impacts for Europe (Beniston and Tol, 1998). A comprehensive assessment of the health impacts of climate change has been undertaken by a Task Group convened by the WHO, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) (McMichael *et al.*, 1996b). Because of the scale of the analysis, the global and Europe-wide reviews do not provide insight into the extent of health effects related to climate change at the national or local level.

Countries that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC) are obliged to undertake national assessments of the impacts of climate change. However, few countries have conducted reviews of the potential health impacts of climate change, these include: Australia (NHMRC, 1991); Japan (Ando, 1993, Ando *et al,* 1998); US (USEPA, 1989); and Canada (CGCP, 1995). The Canadian Global Change Programme (CGCP), set up in 1992, also had a wider remit to identify and prioritise research themes in health sciences related to global change.

Within Europe, national impact assessments, which cover various sectors (e.g. agriculture, industry) have been published for some countries (see Table 1). Only the United Kingdom Climate Change Impacts Review Group (CCIRG, 1996), the Dutch national research programme on global air pollution and climate change (Martens, 1996) and the Czech Republic's climate change country study (Kazmarova et al., 1995; Moldan, 1995) have addressed potential consequences for human health in any depth. A pilot study, carried out by the Potsdam Institute about the potential impacts of climate change on the Brandenburg area, in Germany, also addressed health effects (Stock and Toth, 1996).

The European Commission has recently funded the project: A Concerted Action Towards a Comprehensive Impacts and Adaptation Assessment for the European Union (ACACIA). ACACIA will provide an interim review of current knowledge of potential impacts in all European Union countries and specify research needs for policy making. ACACIA is mostly looking at environmental consequences and only recently addressed human health. The ACACIA report is due to be published mid-2000. Table 2, 3, 4 and 5 list the research programmes addressing the impact of climate change in Europe, funded by the European Union.

Research programmes on climate change and human health are limited in Europe. Projects are currently distributed unevenly between countries with most of the recent scientific activity coming from the Netherlands and the United Kingdom. The Dutch National Research Programme on Global Air Pollution and Climate Change (NRP, 1994) has sponsored some climate change and health research. There has been some involvement of scientists from several other countries.

Table 1. National assessments of the impacts of climate change in European countries

- Finland: Ilmastonmuutos ja Suomi [Climate Change and Finland] (Kuusisto et al., 1996).
- Ireland: Climate Change Studies on the Implications for Ireland (McWilliams, 1993).
- The Netherlands: Systeemverkenning Gevolgen van Klimaatverandering [Studies on Climate Change] (Baan et al., 1993).

- United Kingdom: Review of potential effects of climate change in the United Kingdom (CCRIG, 1996).
- Estonia: UNEP Country Study.[Tarand and Kallaste, 1998; Kallaste and Kuldna, 1998] and US Country Studies Programme vulnerability and adaptation assessment. The Estonian National Report (1996)
- Germany: regional assessment has been completed for Brandenburg but not nationally (Stock and Toth, 1996). The Bay FORKLIM is a regional assessment (association of Bavarian Universities, State Agencies and Federal Research Institutes) but not nationally.
- Sweden: SWECLIM (Swedish Regional Climate Modelling Programme) includes some impacts assessments
- Bulgaria: US Country Studies Programme vulnerability and adaptation assessment Bulgarian Academy of Science (1996)
- Czech Republic: US Country Studies Programme vulnerability and adaptation assessment (Moldan and Sobisek, 1995)
- Russian Federation: US Country Studies Programme vulnerability and adaptation assessment (Izrael, 1997)
- Kazakhstan: US Country Studies Programme vulnerability and adaptation assessment.Kazakh Scienitfic and Research Institute for Environment and Climate Monitoring (1996)
- Slovak Republic: US Country Studies Programme vulnerability and adaptation assessment. (Lapin, 1997)
- Romania: US Country Studies Programme vulnerability and adaptation assessment (Cuculeanu , 1997)
- Ukraine: US Country Studies Programme vulnerability and adaptation assessment (1997)

Table 2. Research programmes within the framework of the EU addressing the impacts of climate change: agriculture, forestry and soils

• Forest Response to Environmental Stress at Timberlines: Sensitivity of Northern, Alpine and Mediterranean Forest Limits to Climate	FOREST
• Predicted Impacts of Rising Carbon Dioxide and Temperature on Forests in Europe at Stand Scale	ECOCRAFT
• Long Term Carbon Dioxide and Water Vapour Fluxes of European Forests and Interactions with the Climate System	EUROFLUX
• Spatial modelling at the regional scale of the response and adaptation of soils and land use systems to climate change	IMPEL
• Model evaluation of experimental variability to improve the predictability of crop yields under climate change	MODEXCROP
• Climate Change, Climate Variability and Agriculture in Europe	CLIVARA
• Climate Change Experiment	CLIMEX II
• Mediterranean Desertification and Land Use (Projects 1, 2 and 3)	Medalus III
• Modelling vegetation dynamics and degree of radiation in Mediterranean ecosystems	MODMED II
• An Integrated Methodology for Projecting the Impact of climate Change and Human Activity on Soil Erosion and Ecosystem degree of radiation in the Mediterranean: A climatological gradient and dynamic systems approach	~
• Wind Erosion and Loss of Soil Nutrients in Semi-Arid Spain	~
• Concerted Action on: Desertification and its relevance to contemporary environmental problems in the Mediterranean	~
• Temporal stability and activity of landslides in Europe with respect to climate change	~
• Long-term effects of CO_2-increase and climate change on European Forests	LTEEF
• Climate change, soil erosion and slope instability in selected agricultural areas of Italy and Southern Britain	~
• European stress physiology and climate experiment: project 2-	ESPACE-GRASS
• Climatic change and agriculture: assessment of impacts and adaptations	CLAIRE
• European stress physiology and climate experiment: project 1 -	ESPACE-WHEAT
• Mediterranean Land Use and Desertification - The MEDALUS Project	MEDALUS
• The likely impact of rising CO_2 and temperature on European forests	~
• A spatial distributed soil, agro-climatic and soil hydrological model to predict the effects of climate change on land use within the European Community	~
• Adaptation of arable crops and perennial vegetation to a changing climate	~
• Climate Change Experiment	CLIMEX
• The effect of rising CO_2 and changing climate on grassland communities in Europe	~
• The Effect of Climate Change on Agricultural and Horticultural Potential in Europe	~
• Agro-climatic change and European soil suitability- a spatially distributed model	ACCESS
• Adaptation, yield and carbon economy of crop pastures in a changing climate	CROP-CHANGE

Source: Livermore, personal communication

Table 3. Research programmes within the framework of the EU addressing the impacts of climate change: water resources, coasts and sea-level change

•	Artificial Recharge of Groundwater	~
•	Impact of Climatic Change on River Basin Hydrology under different Climatic conditions	CC HYDRO
•	Validating Hydrological Moderocess [?] studies and Internal data form Research basins: tools for assessing hydrological impacts of environmental change	VAHMPIRE
•	The Impact of climate change and other hydrological events on European water supply planning and management	~
•	Climate change and coastal evolution in Europe	~
•	Impact of climatic change on North-western Mediterranean Deltas	MEDDELT
•	Groundwater resources and climate change effects	GRACE
•	Evaluation of the effect of climatic variations on the recharge of aquifers in Southern Europe catchments	ECRASE
•	Study on the coastline evolution of the Eastern Po Plains due to sea-level changes caused by climate variations and the natural and anthropic subsidence	~
•	The impact of climate change and relative sea-level rise on the environmental resources of European coasts	~
•	Relative sea-level changes and extreme flooding events around European coasts	~
•	Climate Change, Sea Level Rise and Associated Impacts in Europe	~
•	Impact of climate change on hydrological regimes and water resources in the European Community	~
•	Climate and Sea Level Changes and the Implications for Europe	~

Source: Livermore, personal communication

Table 4. Research projects within the framework of the EU addressing climate change: socio-economic impacts

•	Environmental sustainability and institutional innovation	~
•	Climate change and extreme events: altered risks, socio-economic impacts and policy response	~
•	Institutional adjustment for sustainable development strategies	~
•	The measurement and achievement of sustainable development	~
•	Greenhouse gas abatement through fiscal policy in the European Community	~
•	Designing European governing Institutions for climate futures	~
•	Liens entre prospective, instruments de politiques et critères de décision pour la gestion négociée des risques globaux d’environnement	~
•	Development of an integrated control mechanism for the protection of soil in the Member States of the European Community	~
•	Distributional conflicts as a constraint for national implementation and international harmonization of environmental policy	~

Source: Livermore, personal communication

Table 5. Research projects within the framework of the EU addressing air pollution, UVR, and climate change impacts on human health

♦	Weather impacts on natural and economic systems	~
♦	Indoor/outdoor air quality relationships with respect to building design and climate.	~
♦	Relation of work-related and culture-related patterns of cold exposure to large and paradoxical differences in excess winter mortality within Europe.	~
♦	Peripheral markers for risk assessment of pneumotoxic and nephrotoxic pollutants: mechanistic basis and health significance of intermediate endpoints.	~
♦	Impact of ultraviolet radiation on health nutrition for systemic protection.	UV and nutrition
♦	Skin cancer factors and assessment of adaptive responses to solar ultraviolet radiation exposure.	CANRISK
♦	Risk assessment for exposure to traffic-related air pollution and the development of inhalant allergy, asthma and other chronic respiratory conditions in children.	TRAPCA
♦	Exposure and risk assessment for fine and ultrafine particles in ambient air	ULTRA
♦	Short-term effects of air pollution on health: a European approach to methodology, dose-response assessment and evaluation of public health significance.	APHEA 2

Source: Livermore, personal communication

Governmental agencies and research institutions in the US have taken a more proactive approach than those in Europe. In 1989 the US Environmental Protection Agency (USEPA) submitted a report to US Congress addressing climate change and health impacts for the US (USEPA, 1989). The USEPA is supporting a comprehensive research programme "Integrated assessment of public health effects of climate change for the US" which also supports policy development and analysis (Patz and Ellis, 1998). The mulit-agency US Global Change Research Group (USGCRP) is currently sponsoring "The US National Assessment: Potential Consequences of Climate Variability and Change". A national assessment synthesis team (NAST) will integrate the results of regional and sectoral assessments (USGCRP, 1998). The health sector assessment will address the following questions:

- What are current environmental stresses and issues for the United States that will form a backdrop for potential additional impacts of climate change?
- How might climate variability and change exacerbate or ameliorate existing problems?
- What are the priority research and information needs that can better prepare policy makers to reach wise decisions related to climate variability and change?
- What research is the most important to complete over the short-term? Over the long term?
- What coping options exist that can build resilience into current environmental stresses, and also possibly lessen the impacts of climate change?

In 1996, WHO, WMO and UNEP tentatively established a collaborative network on climate change and human health, which was endorsed in 1997 by the UN Inter-Agency Committee on the Climate Agenda (IACCA, a joint programme of international agencies concerned with climate issues). In May 1998, the World Health Assembly approved these initiatives and requested the Director-General to formalise these agreements and start collaborative actions in support of Member states (resolution WHA 51.29).

Other international bodies are also developing a range of health-related interests and activities. For example, the International Human Dimensions of Global Change Programme (IHDP) is coordinating several workshops in 1999 on the links between environment and health, in conjunction with the International Council of Scientific Unions (ICSU) and the International Geographical Union (IGU) Commission on Health and Development (HED).

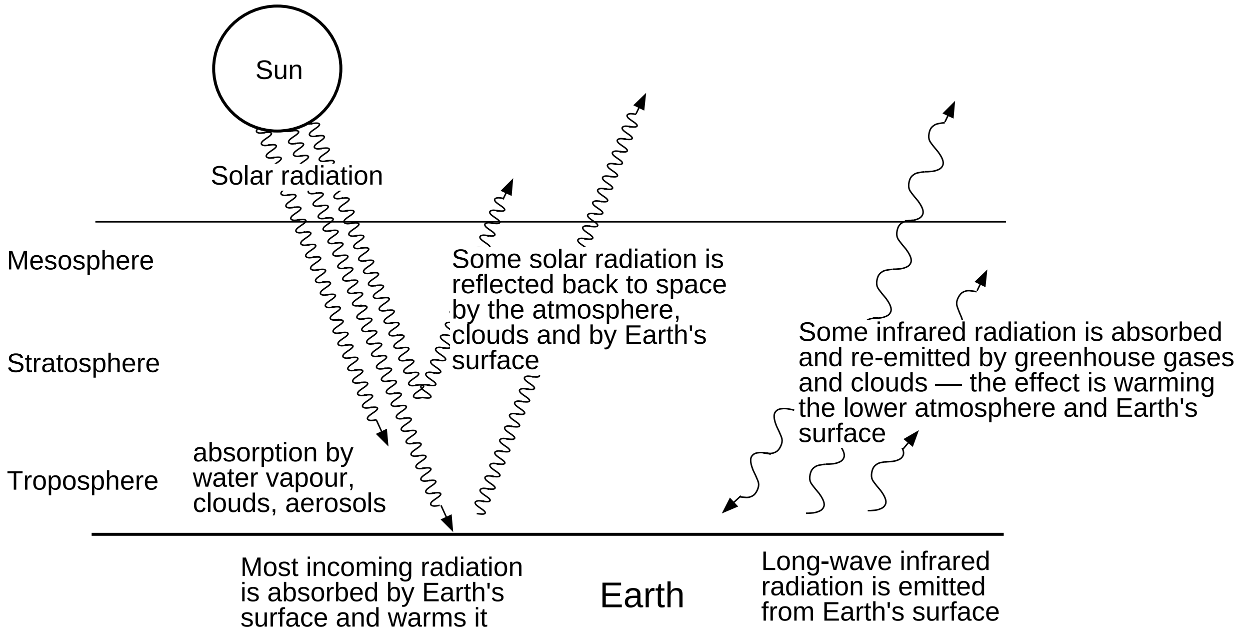
In conclusion, the human health impacts of climate change in Europe are not being systematically addressed by any of the current activities on climate change by agencies in Europe. In particular, the issues of monitoring for early impacts on health and the identification of specific public health actions are not being addressed. There is also a need for a forum to be created to bring together the scientists that are working on health impacts research, so that they can benefit from shared knowledge and experience.

2. Climate change in Europe

Ever since the beginning of the Industrial Revolution (c.1750-1800), the emissions of greenhouse gases (GHGs) have been rising as a result of increased industrial and agricultural production, and increased use of fossil fuel for domestic heating. The atmospheric concentration of carbon dioxide, the main GHG, has increased by 30% since pre-industrial times (IPCC, 1996). Ice-core studies indicate that atmospheric CO_2 concentration is now higher than at any other time in the past 160 000 years - i.e. most of the lifetime of the modern human species.

The main effect of increased concentrations of GHGs has been enhancement of the troposphere's heat-trapping capacity, a process known as radiative forcing. This results in the enhanced greenhouse effect, or global warming (see figure 2). GHG emissions thus are a matter of global concern rather than simply one of local concern.

Figure 2: The greenhouse effect



Source: IPCC, 1994

2.1 Climate in Europe

Climate is determined by latitude or altitude and by a country's proximity to the ocean or an inland sea. In Europe, the annual temperature range varies from some 10° C in coastal regions of the United Kingdom and Ireland, to about 30° C in Finland and Russia. Annual precipitation totals range from as low as 200 mm per year in southern Spain and Greece to over 2,000 mm in coastal regions of Norway and at some locations in the Alps (Beniston and Tol, 1998).

Although much of Europe lies in the northern latitudes, the relatively warm seas that border the continent give most of central and Western Europe a temperate climate, with mild winters and summers. In the Mediterranean area, the summer months are usually hot and dry, with almost all rainfall occurring in winter. In Eastern Europe (from central Poland eastward), moderating drier conditions prevail, accompanied by a greater amplitude of annual variation of temperatures, i.e. hot summers and cold winters. North-western Europe is characterised by relatively mild winters with abundant precipitation along the Norwegian coast and mountains, and much colder winters and generally drier conditions in Sweden and Finland.

The natural variability of climate is becoming better understood. There are natural oscillations within the climate systems, such as the North Atlantic Oscillation (NAO) and the El Nino Southern Oscillation, which affect interannual variability. ENSO is a prominent influence on weather patterns in much of the world but has only weak effects in Europe (Saunders, 1997). The NAO is characterised by changes in ocean circulation in the Atlantic and is a weak determinant of interdecadal and interannual variability in Europe (Hurrell and van Loon, 1997).

2.2 Observed changes in climate in Europe

Worldwide there has been a clear warming trend. Spatially resolved reconstruction of annual surface temperature patterns over the past six centuries showed that out of the mean northern hemisphere temperatures the years 1990, 1995 and 1997 were warmer than any other year since at least AD 1400 (Mann *et al.*, 1998). Climatologists of the IPCC have confirmed that "the balance of evidence suggests a discernible human influence on global climate" (IPCC, 1996b, p.10).

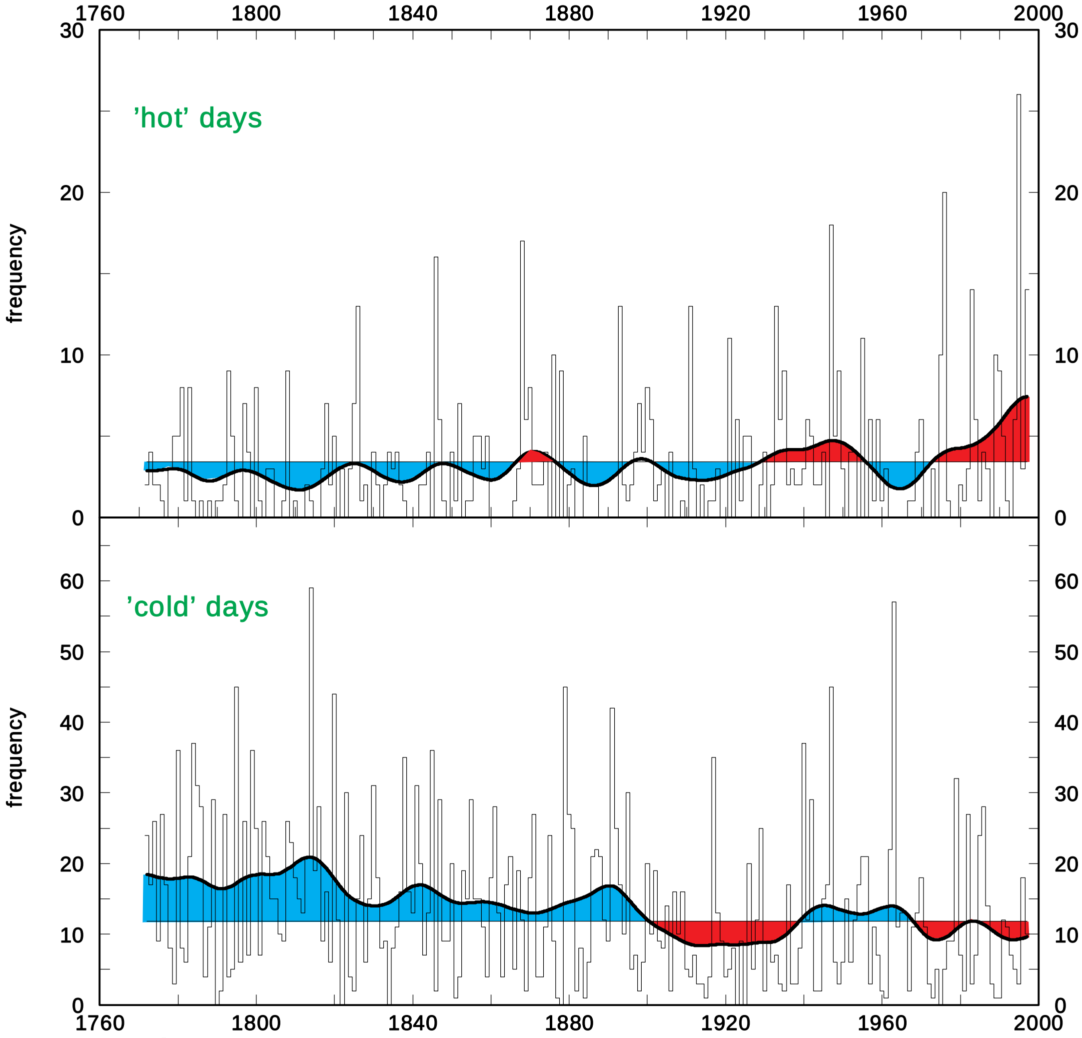
Global temperatures have increased by about 0.6 °C in the last 100 years. In Europe, the warming trend is slightly greater, 0.8 °C (Schoenwiese *et al.,* 1993; Onate and Pou, 1996; Schuurmans, 1996). There have been clear intra-European Regional differences and the warming trend has not been continuous throughout the century (ECSN, 1995). In Greece and parts of Eastern Europe, some stations show a cooling trend.

Warming over most of Europe has been particularly great during the previous decade (i.e. 1981-1990), with increases in annual mean temperature from 0.25-0.5 °C with respect to the long-term average. The warming is most apparent in a band extending from Spain over Central Europe into the Russian Federation. At some high-elevation sites in the Alps, temperature increases have been even more marked, exceeding 1°C in the 1980s (Beniston and Rebetez, 1995; Auer and Boehm, 1994). Minimum temperature increases have been far larger than changes in maximum temperatures, and the observed temperature rise has been most marked during the winter period, which is consistent with evidence from other regions of the world (e.g. US, Karl *et al.*, 1993).

Precipitation has increased in the northern half of Europe, with increases ranging from 10% to 50%. The region stretching from the Mediterranean through central Europe into European Russia and Ukraine, by contrast has experienced decreases in precipitation by as much as 20% in some areas (Beniston and Tol, 1998). However, precipitation trends show complicated patterns in time and space.

Extreme events (e.g. heatwaves, drought, heavy precipitation and storms) are, by definition, rare occurrences. A regional assessment for Europe concluded that there was insufficient times series data to find trends in the frequency of extreme events (ECSN, 1995). An assessment in the US, found that the frequency of extreme precipitation events has increased in recent decades (Karl and Knight, 1998). The United Kingdom has one of the longest climate data series in the world - the Central England Temperature (CET) series, which dates back to 1659. Daily CET data are available from 1772 and indicate that there has been a significant reduction in the number of "cold days" and a more modest increase in the number of "hot" days per decade, particularly the last decade (Hulme and Jenkins, 1998). No long-term trends in annual precipitation or in the frequency severe gales in the United Kingdom were found.

Figure 3: Annual frequency of "hot" (mean temperature above 20° C) and "cold" (mean temperature below 0° C) days extracted from the Central England Temperature record for the period 1772 - 1997. The horizontal lines are the average temperature for 1961-1990 and the smooth curves emphasize thirty-year time scale variability.



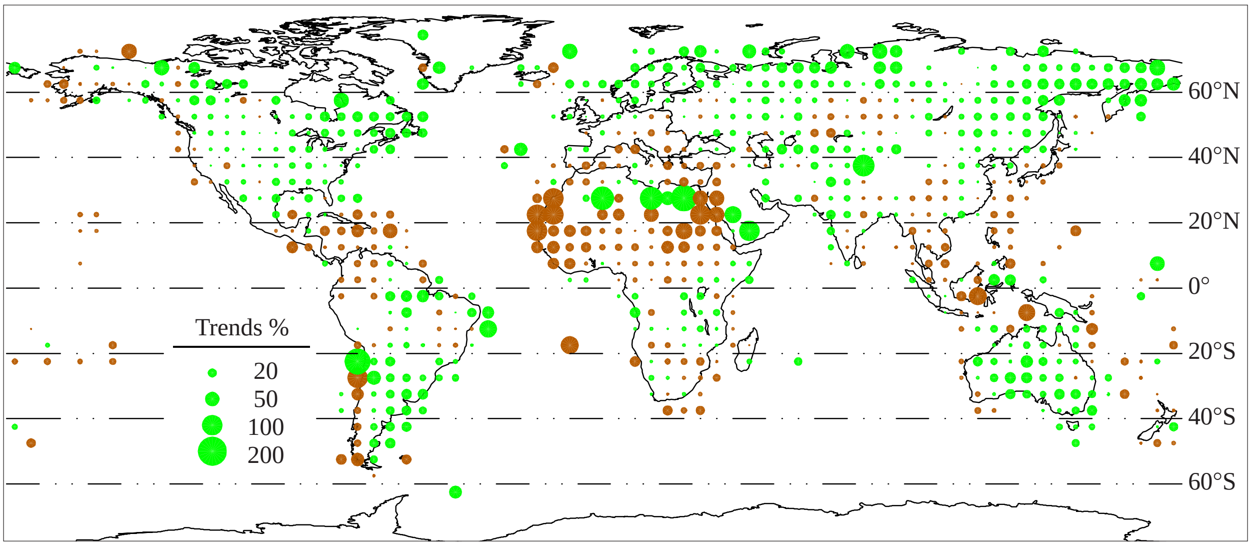
Source: UK Climate Impacts Programme (UK CIP)

Ecological impacts of the observed changes in climate have also become apparent in Europe. Terrestrial plant growth, measured by satellite (which gives an index of photosynthetic activity), has increased in the past decade owing to the extension of the growing season associated with warmer summers (Myneni *et al.*, 1997). The greatest increase lies between 45°N and 70°N, which corresponds to most of Europe, where marked warming has occurred in the spring time (Chapman and Walsh, 1993). An advance of the seasonal cycle of 7 days was observed between 1960 and the early 1990. In northern latitudes (>45°N), the advance of spring is, on average, 12 days. The impact of climate change on mountain regions has also been observed. In the Alps, increased species richness in plants has been observed at lower altitudes and upward expansion of species range at higher altitudes (Grabherr, 1994).

2.3 Projections of future climate change in Europe

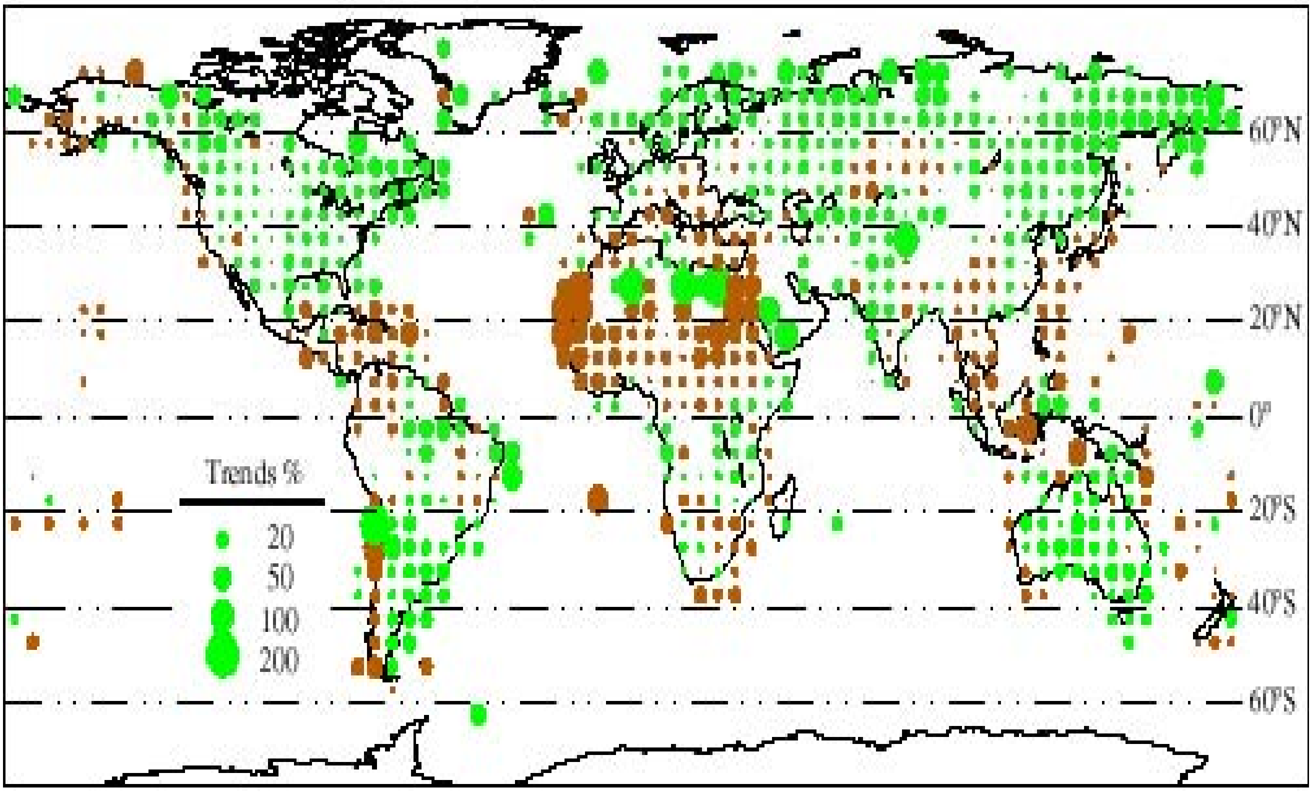
Projections of future climate change are derived from global climate model (GCM) experiments. Climatologists of the IPCC have reviewed the results of these experiments for the recent global and regional assessments (IPCC, 1996b; Beniston and Tol, 1998). The main findings are summarised below for the European Region.

Figure 4: Magnitude of observed trends in annual average temperature for this century (1901-1996). Circles indicate decreasing trends



Source: Beniston and Tol, 1998

Figure 5: Magnitude of observed trends in annual precipitation, expressed as % change per century relative to 1961-1990. Dark circles indicate decreasing trends



Source: Beniston and Tol, 1998

An overall increase in average annual temperatures is projected and this increase is likely to be greater in high (boreal) latitudes than in mid-latitude Europe. Summer temperatures will increase more than winter temperatures. Annual mean warming may be greater in Eastern Europe than in

Southwest Europe. Projected precipitation patterns are more uncertain. In general, continental regions may become dryer while maritime regions may become wetter. Models show an increase in precipitation for Europe as a whole from a higher content of water vapour in the atmosphere. Winter precipitation in high latitudes of Europe, as well as at higher elevations in mountain regions such as the Alps, will increase. Precipitation is expected to decrease in the Mediterranean region and in Central and Eastern Europe.

A major source of uncertainty in these projections is the future concentration and distribution of aerosols. Aerosols are suspensions of particles in the atmosphere that occur naturally and from human activities. By diminishing solar radiation at ground level, aerosols may offset some climate warming. The regional "negative" effect of sulphate aerosols in Central Europe could offset some of the time-dependant "positive" effect of carbon dioxide on climate warming (Mitchell and Johns, 1997). The local effects of aerosols on precipitation patterns are also highly uncertain.

Global climate model outputs have very coarse geographical resolution. Therefore, climate scenarios that are more locally or nationally relevant are produced via downscaling whereby local climatological data are linked to the GCM output. Several regional climate scenarios have been constructed for Europe, often for a sectoral impact assessment exercise (e.g. agriculture - Harrison *et al*., 1995). The climate change scenarios that have been developed for the ACACIA project (see above) are presented in the context of natural climate variability (Hulme et al., forthcoming). National climate scenarios have been constructed by the countries listed in Table 1, although not all have used downscaling techniques.

The possibility of rapid climate change must also be considered. The climate system is not sufficiently understood to rule out a non-linear response to increasing greenhouse gas concentrations. The most likely example is a rapid change in the thermohaline circulation of the world's oceans. The collapse of the thermohaline circulation in the North Atlantic ("the Gulf Stream") could cause cooling over northwest Europe, particularly in the United Kingdom. It has been suggested that under certain climate regimes the thermohaline circulation could flip from an "on" state to the colder "off" state, and there is some evidence that thermohaline circulation has weakened in recent years. GCM experiments in general show a weakening of the thermohaline circulation, but none indicate a dramatic collapse (Hulme and Jenkins, 1998).

2.4 Sea level rise

Global eustatic sea level is forecast to rise 13-94 cm by 2100 from climate change (IPCC, 1996). In Europe, regions, which are vulnerable to increased flooding, include areas, which are already close to or below mean sea level. Vulnerable regions include:

- Dutch coastline;
- North Sea coast, Germany;
- Po River delta, Italy;
- Black Sea coast;

Areas with low inter-tidal variation are also more vulnerable to sea level rise. Such areas include the coastal zones of the Baltic Sea, the Mediterranean and the North Sea/Atlantic coast. Many of Europe's largest cities are built on estuaries and lagoons (for example, Hamburg, London, St Petersburg, Thessaloniki, and Venice) and are therefore vulnerable to sea level rise (Frasetto, 1991).

Most low-lying areas in Europe are already protected from coastal flooding and it is anticipated that countries will maintain and strengthen coastal defences as it has been shown to be cost-effective to do so. However, changes in the nature and frequency of storm surges, particularly in the North Sea, are likely to be of considerable importance for many low-lying coastal areas (Beniston and Tol, 1998).

Nicholls and Mimura (1998) have evaluated the policy implications of sea-level rise. The slow but steady degradation of the coastal fringe in much of Europe has gone largely unnoticed until recently. This trend is likely to continue and accelerate with sea-level rise. Some studies have estimated future populations at risk of flooding under sea level rise projections. Table 6 illustrates some assessments for the Netherlands, Germany and Poland.

The collapse, loss of most of the land-based ice of the West Antarctic Ice Sheet (WAIS) on a timescale that is much shorter than its accumulation turnover timescale, would entail a much more rapid sea level rise than currently forecast. Complete disintegration would raise sea levels by 4-6 metres (Oppenheimer, 1998). Further to the possibility of rapid climate change, the potentially catastrophic risks of climate change must be considered.

Table 6. Assessment of population at risk of sea level rise

Country	**SRL scenarios**	**People affected**		**People at risk**		**Capital value loss**		**Land loss**		**Wetland loss**	**Adaptation/protection costs**	
	(m)	No of People (100s)	% total	No. of People (1000s)	% total	Million US $	%GNP	Km2	% total	Km2	Million US $	%GNP
The Netherlands	1.0	10000	67	3600	24	186000	69	2165	6.7	642	12300	5.5
Germany	1.0	3200	3.9	309	0.3	7500	0.05	13900	3.9	2000	23500	2.2
Poland	0.1	Na	Na	25(18)	0.1 (0.05)	1800	2	na	Na	Na	700+4	2.1+0.01
	0.3	Na	Na	58 (41)	0.1 (0.1)	4700	5	845	0.25	Na	1800+8	5.4+0.02
	1.0	235	0.6	196 (146)	0.5 (0.4)	22000	24	1700	0.5	na	4800+400	14.5+1.2

Results are for existing developments and all costs have been adjusted to 1990 US$. People affected, people at risk, capital loss, land loss and wetland loss assumes no human response, whereas adaptation assumes protection except in areas with low population density.
Na: not available, people at risk = the number of people flooded by storm surge in an average year.
(results in parenthesis)= people who will be flooded more than once a year
Adaptation/protection costs for Poland, include capital and annual running costs, while %GNP assumes costs are all incurred in one year

Source: Nicholls and Mimura, 1999

2.5 Impact of climate change on water resources

Water is one of the main integrating factors for many environmental and economic systems in Europe. Under current climate conditions, many areas have problems with water supply. Climate change is likely to enhance water-related stresses in these areas (Beniston and Tol, 1998).

Areas vulnerable to water stress include:
- the Mediterranean region;
- the Alps;
- northern Scandinavia;
- certain coastal zones;
- Central and Eastern Europe.

In a warmer climate, water availability will be reduced by increased evapo-transpiration. However, the response of hydrological systems depends on many factors, such as the distribution of precipitation and storage capacity. Many regions will experience a general decrease in runoff, though according to region the change in runoff may range between -5% and + 12%. More droughts are expected in southern Europe (Beniston and Tol, 1998). The potential for winter and springtime flooding will be greater in Northern and Northwest Europe.

2.6 Stratospheric ozone depletion

Stratospheric ozone is thought to have begun forming several billion years ago as a result of the solar-powered destruction and recombination of oxygen. The natural concentration of stratospheric ozone is now maintained through the dynamic equilibrium existing between production and destruction of ozone. The latter reaction is catalysed by trace amounts of hydrogen, nitrogen and halogen free radicals (particularly chlorine and bromine). These radicals occur naturally but, in recent decades, their concentration has been increased greatly by industrial activities. This has upset the aforementioned equilibrium and led to a sustained decline in stratospheric ozone concentrations (Molina and Rowland, 1974; WMO *et al.*, 1994).

Stratospheric ozone depletion, as with greenhouse gas accumulation in the lower atmosphere, entails changes in the global climate - the "global commons". That is, although the gaseous emissions arise from diverse localised sources, in all continents, their environmental impact is of a diffuse globalised kind. Local emissions thus contribute to an integrated global change, which has potentially serious consequences for human health.

Significant stratospheric ozone losses have occurred mainly at middle and high latitudes. Ozone depletion is more pronounced in winter and spring than in summer (UNEP, 1994). These seasonal differences are more marked in the Northern Hemisphere, although, in general, ozone depletion is more pronounced in the Southern Hemisphere. Ozone depletion over Europe has been approximately 3% per decade (UNEP, 1998).

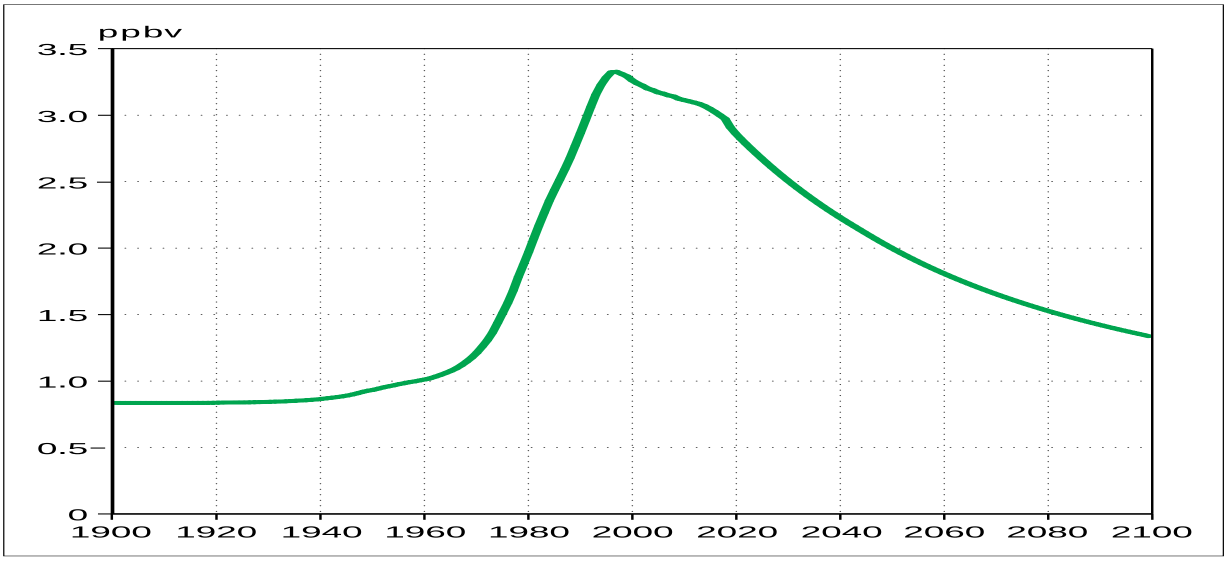
Stratospheric ozone shields the Earth's surface from incoming solar ultraviolet radiation (UVR) which is harmful to all animals and plants. Increases in ground-level UVR are presumed to have occurred, particularly at higher latitudes. However, such trends are difficult to ascertain because the recording of wavelength-specific UVR measurements has only recently begun. In addition, local factors such as clouds, aerosols and tropospheric ozone pollution can absorb or reflect UVR before it reaches the ground.

Increases in biologically active radiation (i.e. the UV band which causes erythema) for the period 1979-92 are estimated by UNEP (1998) to have been:

- Latitude 40-50 N - 3.5 % per decade
- Latitude 50-60 N - 5 % per decade
- Latitude 60-70 N - 4 % per decade

A phasing out of CFCs and other halocarbons was agreed to internationally in the Montreal Protocol (1987) and in its London (1990), Vienna (1995) and Montreal (1997) Amendments, and Copenhagen adjustment. Nevertheless, the concentration of stratospheric ozone is not expected to return to its normal level until the second half of the next century. There is also some evidence that some countries are not observing the global ban on CFCs, and illegal trade in these substances would compromise the recovery of the ozone layer

Figure 6: Projections of ozone layer recovery under Montreal Protocol and its Amendments



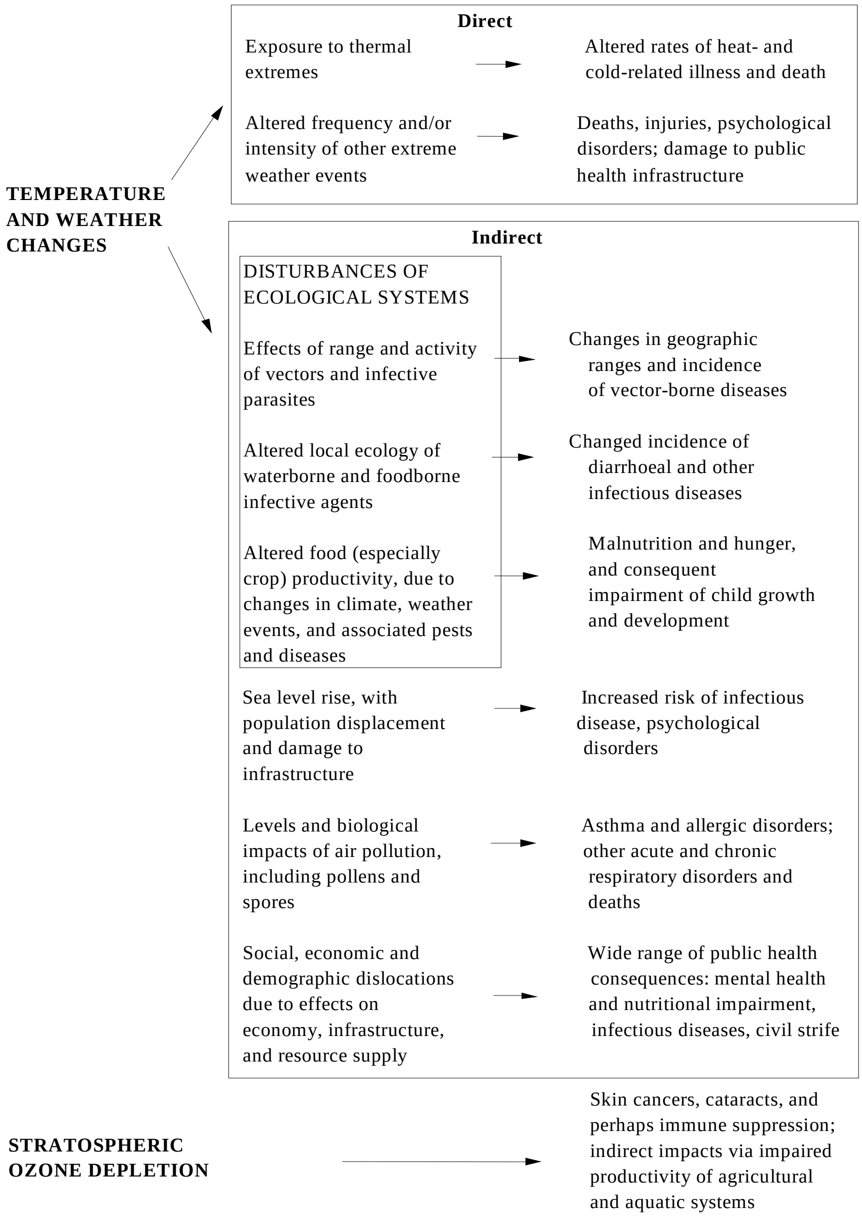
Note: The curve shows the projected mixing ratio (frequency of occurrence) of so-called equivalent effective chlorine. It is based on the Protocol scenario in the 1998 WMO/UNEP ozone assessment, where one assumes the maximum allowed emissions within protocols.
Source: Preliminary data from the WMO 1998 ozone assessment (Guus Velders, RIVM).

Some recent evidence indicates that global warming may alter the atmospheric heat budget so as to increase the cooling of the stratosphere (IPCC, 1996). If such stratospheric cooling continues, the risk of ozone depletion could continue to increase even after chlorine and bromine loading starts to decline. Shindell *et al.* (1998) have estimated that the projected increase in GHG concentrations, and subsequent tropospheric heat-trapping, may increase polar ozone losses and thus delay the eventual recovery of the ozone layer.

3. Health impacts of climate change in Europe

Authoritative international reviews have concluded that climate change will affect human health, mostly in adverse ways (McMichael *et al.,* 1996b). The impacts of stratospheric ozone depletion are addressed separately in the next section.

Figure 7: The major types of impact of climate change and stratospheric ozone depletion on human health



Source: McMichael, 1996b

A major problem assessing future health impacts is the lack of research on most questions related to weather, climate and health. Indeed, climate change impacts have been identified as a research priority for environment and health in Europe by the European Science Foundation (EC/ESF/WHO-ECEH, 1998).

The health impact assessment of global climate change has three distinctive features: (i) the large spatial scale; (ii) the timing and the potentially long temporal scale; and (iii) the level of complexity in the systems being studied. Further, health impact assessments must accommodate multiple uncertainties that compound across antecedent environmental and social changes (McMichael and Martens, 1995). Some health impacts of global climate change can be estimated by reasonable 'extrapolation' of relatively simple cause-effect models. For example, a change in ambient temperature is expected to change the number of temperature-related deaths. However, this may not be appropriate if the health risk concerned is linked to an ecological process. Infectious diseases are the most obvious example of a category of health problem with complex ecologically based dynamics. Climate change impacts on population health will reflect the conditions of the ecological and social environments in which humans live. Our health is profoundly affected by various natural systems such as the ecology of pests and pathogens, food supplies, water supplies, climatic conditions and weather patterns. In addition, climate change will not affect human health in isolation, but will do so simultaneously with other ecological and demographic changes.

The most important research methods for forecasting future health impacts are (McMichael *et al.*, forthcoming):

- empirical studies of climate/health relationships, useful as analogues for future climate change;
- studies of early impacts of climate change, where applicable;
- predictive modelling;
- generalised assessments of the range of health consequences of diffuse and complex demographic, social and economic disruptions.

In epidemiological terms, the climate 'exposure' is either a direct measure of climate or weather (e.g. precipitation, temperature) or an indirect measure of the impact of climate on ecological or social systems that affect health. Such climatic exposures can be described in three broad temporal categories: long-term changes in means or norms; inter-annual (or decade) variability; and isolated extreme events such as floods, droughts, or storms. These categories are not independent. Extreme events are a function of climate variability and any shift in the mean will, for a given distribution, affect the frequency of extreme events.

Further, impact assessment of climate change must consider both the sensitivity and vulnerability of populations for specific health outcomes to climate change. In particular, the following aspects must be considered (IPCC, 1996):

- How sensitive is a particular system to climate change, i.e. how will the system respond to a given change in climate?
- How adaptable is the system, i.e. to what degree are adjustments in practices, processes, or structures of systems, likely to impact either actual or projected climate change? Adaptation can be spontaneous or planned, and can be carried out in response to, or in anticipation of changes in conditions.
- How vulnerable is a system to climate change, i.e. how susceptible to damage or harm? Vulnerability depends on both sensitivity and adaptability.

With the uncertainty regarding potential impacts on human health, it is essential to focus on describing and reducing population vulnerability.

3.1 Thermal stress

Global climate change will be accompanied by an increase in the frequency of heatwaves, as well as warmer summers and milder winters. Even with no change in climate variability, an increase in mean temperatures would increase the number of summer heatwaves (as currently defined) and reduce the number of cold spells in winter, for any given location. It has been projected that the equivalent of the extremely hot 1976 summer in the United Kingdom, very unlikely in today's global climate (i.e. occurring once every 310 years), would occur every 5-6 years under the anticipated warmer climate of 2050 (Hulme, 1996).

Although a warming trend in mean annual temperatures has been observed in Europe (see above), there is very little information on historical trends in extreme temperature episodes (heatwaves or cold spells). An analysis of mean daily temperature records for Athens from 1983 to 1995 found no trend in the frequency of extreme events (Katsouyanni and Touloumi, 1998), but this is consistent with the lack of an observed warming trend in that country. The Central England Temperature series, however, does indicate an increase in the number of days with mean temperature over 20° C in recent decades in central England.

Analyses of daily meteorological and mortality data in cities in Greece, Germany, the Netherlands and the Middle East show that, overall, mortality rises as summer temperatures increase (Katsouyanni *et al.*, 1993; Jendritzky *et al.*, 1997; Kunst *et al.*, 1993; McMichael *et al.*, 1996b). A U-shaped relationship has been widely observed between daily temperature and mortality in these cities and others in temperate regions. Thus, mortality is lowest within an intermediate comfortable temperature range. In Greece, the temperature mortality relationship is a J-shaped curve, with lowest mortality observed when daily temperature is approximately 23 °C (Katsouyanni and Touloumi, 1998). A similar shape has been observed in the Netherlands with lowest mortality about 16 °C, where average temperatures are lower than in Greece (Kunst *et al.*, 1993). The rate of increase in deaths as daily winter temperature decreases appears to be considerably less steep than that accompanying increasing temperatures in summer. Thus, mortality appears to be more strongly associated with temperature for heat-related deaths than for cold-related deaths, although the latter occur over a much greater temperature range.

For temperatures above that intermediate comfortable range, there is sometimes a "threshold" above which mortality increases markedly (Kalkstein and Tan, 1996). The threshold temperature is related to population location. No threshold-effect has yet been shown in any European populations.

Episode or time-series analyses have been used to determine the "acute" effects of hot weather on populations. Daily mortality from all causes has been shown to increase during heatwaves. Several episode studies have estimated the excess mortality associated with heatwaves or acute heat episodes in Europe. Extremes of temperature cause physiological disturbance and ill health. Much of the excess mortality attributable to heatwaves is from cardiovascular, cerebrovascular and respiratory disease and these deaths are not certified as heat-related. It is therefore likely that, during hot weather, persons suffering from such diseases experience additional health problems. Several studies have observed that the elderly are particularly vulnerable to heat-related illness (e.g. Faunt *et al.*, 1995).

Many countries in Europe, and elsewhere, have an ageing population. The European Commission has estimated that, by the year 2025, the population of retired adults (i.e. those aged 60 and over) in the European Union will increase by 37 million, that is an increase of 50 % (ETAN, 1998). Therefore, the population vulnerable to thermal stress will increase and climate change will represent an additional burden on this population.

The impacts of some of heat episodes have been documented. For example,

- A heatwave in July 1976 in London, United Kingdom, was associated with a 15% increase in mortality, approximately 520 excess deaths (McMichael and Kovats, 1998a).

- A heatwave in 1994 in Belgium was associated with a 13.2% increase in mortality in the elderly (Sartor *et al.*, 1995).
- A heatwave in July-August 1995 in London, United Kingdom (immediately following the severe Chicago heatwave of that July) was associated with a 15% increase in mortality (Rooney *et al.*, 1998).

A heatwave in July 1987 in Athens, Greece was associated with 2000 excess deaths (Katsouyanni *et al.*, 1988). In all urban areas except Athens, a 32.5% increase in mortality was observed in July 1987 compared to the average July mortality for 1981-1986 (Katsouyanni *et al.*, 1993).

There remains a need to establish the magnitude of these impacts in terms of lost person-time and clarify the public health significance of the so-called "harvesting phenomenon". Occurrence of the "harvesting" phenomenon means that a proportion of the deaths occur in susceptible persons - the frail or sick - who were likely to have died in the near future. More formal analysis and quantification of the harvesting effect is needed. Similarly, many questions about the interaction between high temperature and high concentration of air pollutants need to be resolved. Some of the heatwaves described above were associated with major pollution episodes.

Physiological or "autonomous" adaptation will clearly mitigate some of the impacts of future increases in the frequency or intensity of heatwaves. Physiological acclimatisation to hot environments can occur over a few days, but complete acclimatisation to an unfamiliar thermal environment may take several years. There is some evidence of acclimatisation to hot weather at the population level. The impact of the first heatwave on mortality is often greater than the impact of subsequent heatwaves in a single summer (McMichael *et al.*, 1996b). This effect can also be explained in part by the accumulating deaths of susceptible individuals i.e. towards the end of the summer there are fewer people alive to die in a heatwave.

Much of the published research on climate change, temperature, and mortality has been done for North American urban populations (e.g. Kalkstein and Greene, 1997). There is a clear need to expand the knowledge base by studying populations in Europe and around the rest of the world.

3.1.1 Decreased mortality from too milder winters

In cold and temperate locations, daily deaths increase as daily wintertime temperature decreases (Khaw, 1995; Laake and Sverre, 1996). However, this rate of increase appears to be considerably less steep than the relationship between mortality and increasing temperature in the summer (see above). Thus, in countries in northern Europe, there is a clear-cut seasonal variation in mortality with death rates during the winter season 10-25% higher than those in the summer (Kilbourne, 1997). A study in Germany, suggests that the increased use of central heating has contributed to a steady decline in winter mortality from 1946 to 1995 (Lerchl, 1998).

In Europe, excess winter mortality is particularly high in the United Kingdom (Curwen, 1990; McKee, 1989). Indeed, relative excess winter mortality in the United Kingdom is approximately twice that in Scandinavian countries (Laake and Sverre, 1996) and Russia (McKee *et al.*, 1998). Social and behavioural adaptations to cold play an important role in preventing winter deaths in high latitude countries (Donaldson *et al.*, 1998). The social or behavioural causes of the large winter excess mortality in the United Kingdom are not well understood. Seasonal patterns of respiratory infections such as influenza are a significant cause of winter deaths, particularly in epidemic years. Diet may also play a role in winter mortality in the elderly.

A direct increase in mean summer and winter temperatures associated with global climate change would mean fewer cold spells. Many countries with a high proportion of deaths in winter, such as those in the United Kingdom, are likely to experience a reduction in total winter mortality from milder winters under climate change. Langford and Bentham (1995) estimated that 9000 wintertime deaths per year could be avoided by the year 2025 in England and Wales under a 2.5°C increase in average winter temperature. A meta-analysis by Martens (1997) estimated that an increase in global temperature of 1°C could result in a reduction in winter cardiovascular mortality in Europe.

However, the recent "Eurowinter Study" indicates that southern European populations are more vulnerable than their northern counterparts to short-term cold spells (Eurowinter Group, 1997). Northern European countries may experience a net reduction in excess seasonal deaths, whereas southern European countries may experience a net increase.

3.2 Climate change and urban air pollution

Air pollution in urban areas is a major concern for environmental health in Europe, particularly the impacts of particulate (Bertollini *et al.*, 1996). The spread and concentration of air pollutants (both particles and gases) are dependent on the prevailing weather conditions - air currents, temperature variation, humidity and precipitation. Large, slowly moving anticyclones may cover an area for several days, or a week or more, and give rise to conditions that readily allow pollutants to accumulate. It is therefore very difficult to predict the impact of climate change on average local air pollution concentrations. However, forecasts of climate change in the United Kingdom indicate an increase in anticyclonic conditions in summer (with a decrease in anticyclonic conditions in winter and spring) which would tend to increase air pollution concentrations in cities (Hulme and Jenkins, 1998).

The formation of secondary air pollutants, such as ozone, is a photochemical reaction. Therefore, the rate of reaction increases at higher temperatures and increased levels of sunlight. It is anticipated that climate change would entail an increase in average ambient concentrations of ozone, all other things being equal, and an increase in the frequency of ozone pollution "episodes". The relationship between ambient temperature and ozone concentration is not linear. In one study, ozone concentration increased above a temperature threshold (90° F or 32.2°C). USEPA (1989) has estimated, based on US data, that a 4 °C rise in mean annual temperature would cause a 10% increase in peak ozone concentrations. This would double the number of cities in the US that currently exceed the national air quality standards for this pollutant. The model assumed that precursor vehicle emissions and other weather factors (e.g. the frequency of anticyclonic conditions) were unchanged. Increased ground level UVR from stratospheric ozone depletion would also increase the concentration of ozone.

The "acute" impacts of air pollutants upon daily mortality seem to be mainly from particulates and acid aerosols. Ozone also has adverse effects on all-cause mortality in European cities (Touloumi *et al.*, 1997). High temperatures also have acute effects on mortality, as discussed above. In most epidemiological studies of air pollution impacts, temperature is treated as a confounder. Few studies have addressed the need to quantify and describe the separate impacts on mortality and morbidity of air pollution and thermal stress. There is some evidence of a physiological synergistic effect between high temperatures and pollutants (Katsouyanni *et al.*, 1993).

3.3 Aero-allergens

The production of many aeroallergens in the air, particularly pollen, depends on the season of the year. For example, the start of the grass pollen season in the United Kingdom can differ by about 32 days according to the weather in the spring and early summer. However, trends in pollen abundance are more strongly linked to land use change and farming practices than climate (Emberlin, 1994). Hay fever consultations have been shown to coincide with the onset and duration of pollen season. Climate change is likely to change the seasonality of pollen-related disorders such as hayfever. However it is not yet known whether this would entail a season of longer duration in addition to an earlier onset. There are local differences in sensitivity to different pollens and this makes forecasting future health impacts difficult.

As with many atopic diseases, prevalence of hay fever is rising in Europe for reasons that are not clear, but are not to do with climate change. Thus, small changes in seasonality may affect a large number of people and the aggregate impact of climate change on health care services might be significant.

The relationship between climate change and respiratory diseases is complex. Curson and Beggs (1996) has developed an integrated environmental model of asthma, but it is not quantitative. Climate change is likely to have impacts on (indoor) cockroaches, mould/fungi, damp in modern building materials, dust mites and (outdoor) pollen and air pollutants.

Asthma seasonality is complex and not well understood. In the United Kingdom, for example, seasonal peaks vary between age groups suggesting different causative factors (LAIA, 1993). Only a small percentage of asthma admissions is estimated to be related to pollen allergens (approximately 10%) (Anderson, 1995). Therefore, climate change may affect the seasonality of some asthma cases - see above.

3.4 Extreme weather events: storms and floods

Major impacts of climate change on human health are likely to occur via changes in the magnitude and frequency of extreme events (Downing *et al.*, 1996). Climate change projections are based on the anticipation of increasing means or norms. Global or regional climate models are not well able to forecast future climate variability, whether daily, interannual or decades. Changes in extreme events are forecast by estimating changes in probability distributions.

There is an increasing trend in natural disaster impacts in Europe and globally. An analysis by the Reinsurance Company Munich Re (1998) found a three-fold increase in the number of natural catastrophes in the last ten years, compared to the 1960s. This trend is primarily from global trends, which affect population vulnerability rather than changes in the frequency of extreme events. Reasons for the observed increase in "disasters" in the European context are:

- increasing concentration of people and property in urban areas;
- settlement in exposed or high risk areas (e.g. flood plains, coastal zones);
- changes in environmental conditions (e.g. deforestation can increase flood risk)

Several assessments for Europe have concluded that the risk of river flooding will increase. The hydrological cycle will be more intense in a warmer climate. This will entail more heavy rainfall events and an increased risk of flooding and landslides. Droughts may increase in arid and semi-arid regions, where increased rainfall is not able to compensate for increased evapo-transpiration. Regional and national assessments of the increased risk of flooding under climate change have been made (Beniston and Tol, 1998). Coastal flooding will also increase due to sea level rise unless sea defences are upgraded appropriately (Nicholls and Mimura, 1998).

Floods are the most common trigger for a natural disaster. Recent devastating floods in Europe affected Poland, the Czech Republic, Germany, Netherlands, Norway, Russia, Romania, France and Italy.

Table 7. Serious floods in the 1990s in Europe

Flood events (river/year)	**Fatalities**	**Damage costs (bilion ECU)**	**Remarks**
Tazlau (Romania)	107	0.05	Breakdown of the Tazlau dam
Ouveze 1992 (France)	Nearly 100		Campsite
Rhine/Meuse 1993/94	10	1.1	
Po 1994	63	10	Catchment area covered by up to 60 cm of mud
Rhine 1994/1995	None	1.6	Evacuation of 240 000 inhabitants in the Netherlands
Glomma and Trysil River Basins (Norway) 1995	None	0.3	
Pyrenean river 1996	85		Campsite
Oder, Labe, Vistula and Morava 1997	95	5.9	195 000 people evacuated, great material losses
Lena (Republic of Sakha, Yakutia, Russia), 1998	15	1.300 million roubles	51.295 people evacuated, complete interruption of transport system, great material loss

Source: EEA, 1998 adjusted by Menne, 1999

With the exception of floods generated by dam failure or landslides, floods are climatological phenomena which are influenced by the geology, geomorphology, relief, soil, and vegetation conditions (Ward, 1978). Floods may also be intensified by human alteration of the environment such as alterations in the drainage patterns from urbanisation, agricultural practices, deforestation and the use of improper construction techniques. Meteorological and hydrological processes can be fast or slow and can produce flash floods or more predictable slow-developing river floods.

Flash floods have two characteristics. First they follow a causative event- such as excessive rainfall in a catchment system or sudden release of water in a natural or human made dam, within minutes or hours and with high velocity flows and great volumes of water. Second, with flooding commonly lasting less than 24 hours (Alexander, 1993), they are accompanied by an extremely short warning and response time, with potential for great loss of life (Gruntfest *et al.*, 1991). Riverine floods usually result from rainfall or meltdown of snow and ice and are more slow rising.

The primary cause of death from floods is drowning followed by various combinations of trauma and hypothermia with or without submersion. Among survivors of floods, the proportion of people requiring emergency medical care is reported to vary between 0.2% and 2%. Most injuries requiring urgent medical attention are minor, and include lacerations, skin rashes, and ulcers. However, flood-associated lacerations are frequently contaminated (Noji, 1995).

Much of the effect of flooding upon mortality and ill health may be attributable to the distress and the psychological effects of the event. Following flooding in Bristol, UK, primary care attendance rose by 53% and referrals and admissions to hospitals more than doubled (Bennet, 1970). Similar psychological effects were found following floods in Brisbane in 1974 (Abrahams *et al.*, 1976). An increase in psychological symptoms and post-traumatic stress disorder including 50 flood-linked suicides were reported in the two months following the major floods in Poland in 1997 (IFRC, 1998).

3.4.1 Infectious disease implications of floods

During and following both catastrophic and non-catastrophic flooding, there is a risk to health if the floodwaters become contaminated with human or animal waste. In developed countries, like many in Europe, disease risks from flooding are greatly reduced by a well- maintained sanitation infrastructure. In addition, public health measures undertaken during a flood have often been successful in preventing outbreaks. Such measures include monitoring and surveillance activities to detect and control outbreaks of infectious disease.

From a public health point of view, floods may disrupt water purification and sewage disposal systems, cause toxic waste sites to overflow, or dislodge chemicals stored above ground. In addition, makeshift evacuation centers with insufficient sanitary facilities may become substantially overcrowded. The combination of these events may contribute to increased exposure to highly toxic biologic and chemical agents. Examples include the potential for water-borne disease transmission of such agents as enterotoxigenic Escherichia coli, Shigella, Salmonella, and hepatitis A virus. An epidemic of leptospirosis was associated with floods in the Ukraine in 1997 and in the former Yugoslavia, flood-related outbreaks of epidemic nephropathy have also been reported (Kriz, 1998). Analysis of surveillance data following the major floods in 1997 suggests that there was an increase in cases of leptospirosis in the Czech Republic (Kriz *et al.*, 1998).

Flooding in Lisbon, Portugal, in 1967 was linked with a small outbreak of Weil's disease; a total of 32 cases was estimated on the assumption that only a third of cases are reported (Simoes *et al.*, 1969). There may be an increased risk of transmission of malaria, and yellow fever because of enhanced vector-breeding condition.

A number of studies have established a link between dampness in the home, including occasional flooding, with a variety of respiratory symptoms. For example, a Canadian study found that flooding was significantly linked to childhood experience of cough, wheeze, asthma, bronchitis, chest illness, upper respiratory symptoms, eye irritation and non- respiratory symptoms (Dales *et al.*, 1991). In 1998 the massive flooding of the river Lena in the north-eastern republic of Sakha (Russia) one of the most serious problem reported were respiratory tract infection. Very little is known about the occurrence of other diseases, such as skin diseases.

3.5 Foodborne diseases

The epidemiology of foodborne diseases is rapidly changing as newly recognised pathogens and well-recognised pathogens increase in prevalence or become associated with new food vehicles. Different factors contribute to these changing. One of this factor is the fluctuation in ambient temperature (FAO/WHO, 1998). In fact, a seasonal pattern is often observed with cases of foodborne disease peaking in the summer months. Another risk factor is incorrect food- related behaviour, such as inadequate refrigeration, the use of unsafe raw materials and inadequate handling (FAO/WHO, 1998) However, inappropriate food-behaviour in combination with warmer springs and summers, and milder winters, may contribute to the increase of the incidence of foodborne diseases.

A study of reported cases of foodborne illness in the United Kingdom for the period 1982-1991 found a strong relationship between incidence and temperature in the month preceding the illness (but not between rates of foodborne illness and temperature in the month in which illness occurred) (Bentham and Langford, 1995). This relationship was subject to a threshold effect; below 7.5°C no relationship was observed, but above this temperature the relationship was very strong. Assuming maintenance of current systems, it would appear that food-poisoning incidence will rise in the United Kingdom during the next half century in response to temperature change. Increases in food-poisoning cases are estimated at between 5% and 20% per month by 2050, with the highest proportional monthly increases predicted to occur in spring and autumn (Bentham and Langford, 1995).

3.6 Water-related diseases

Water-related diseases can be divided into four categories (Cairncross and Feachem, 1993):

- Faecal-oral diseases spread via water or food that is contaminated with faecal material. They include diseases transmitted by direct ingestion of the pathogen and those spread because of the lack of water for personal hygiene purposes. Examples include cholera, typhoid, hepatitis A, and diarrhoeal diseases.
- Strictly water-washed diseases spread from one person to another, exacerbated by lack of water for personal hygiene purposes. These include infections of the skin and eye (e.g. scabies, trachoma) and infections carried by lice (e.g. louse-borne epidemic typhus).
- Water-based diseases caused by pathogenic organisms that spend part of their life cycle in aquatic organisms and often associated with standing water. In Europe, an example of such a disease would be cercarial dermatitis.
- Diseases spread by water-related insect vectors. These vectors breed in water and include mosquitoes, which transmit malaria and dengue.

The incidence of waterborne outbreaks of disease is widespread throughout the region – in Nordic countries approximately 100 outbreaks were reported in community systems and 40 in non-community systems between 1975 and 1991. Since the early 1980s, organisms which had not previously been regarded as waterborne agents have been identified in outbreaks in the WHO European Region - *Campylobacter, Norwalks agent, Giardia* and *Cryptosporidium* and in around 60% of outbreaks the aetiological agent is not identified. (Thysson *et al.*, 1999)

Faecal-oral diseases are still a major public health problem in Europe. More than 12% of the population in the WHO European Region does not have access to safe drinking water (Bertollini *et al.*, 1996). The majority of this population is in countries in Eastern Europe where acute diarrhoeal diseases are still a major cause of childhood sickness. Two-thirds of infant deaths in Azerbaijan, Armenia, Georgia, Belarus and Moldova are caused by acute respiratory infection and diarrhoeal diseases. Cholera outbreaks continue to be reported from Albania, the Russian Federation, and the Ukraine. Hepatitis A is endemic and has a high prevalence in Central and Eastern Europe and the newly independent states.

The most significant water-borne disease associated with the public water supply in Western Europe is cryptosporidiosis. Cryptosporidium is an intracellular parasite of the gastrointestinal and respiratory tracts of numerous animals. Cryptosporidium oocytes can survive several months in water at 4°C and are among the most chlorine-resistant pathogens. When contamination occurs, it has the potential to infect very large numbers of people. This is illustrated by an outbreak of cryptosporidiosis in Milwaukee, USA, which affected more than 400.000 persons in 1993 (Mackenzie, *et al.*, 1994). Approximately, 5.000 cases of cryptosporidiosis are reported each year in the United Kingdom. A preliminary study in the USA has suggested a link between heavy rainfall events and outbreaks of this disease as the capacity of conventional filtration plants is often exceeded under such conditions (Patz *et al.*, 1998).

Cercarial dermatitis is a water-based parasitic disease that is emerging in Europe (de Gentile *et al.*, 1995). The intermediate hosts are snails of the genus *Lymnea*, the abundance of which may increase in a warmer climate. Control of the disease is difficult, requiring strict maintenance of water bodies and the use of molluscicides.

The complex relationships between human health and problems of water quality, availability, sanitation and hygiene are extremely difficult to quantify. For example, there are multiple routes of faecal-oral transmission. Predicting the potential impacts of climate change on water-related diseases therefore becomes even more difficult. Furthermore, any attempt to do so must take into account water management practices, the growth in demand for water, and a number of other factors not related to climate.

Climate change could have a major impact on water resources and sanitation in situations where water supply is effectively reduced. This could in turn reduce the water available for drinking and bathing, and lower the efficiency of local sewage systems, leading to an increased concentration of pathogenic organisms in raw water supplies. Additionally, water scarcity may necessitate use of poorer quality sources of fresh water, such as rivers, which are often contaminated. All of these factors could result in an increased incidence of diarrhoeal diseases.

3.7 Vector-borne diseases

Several important diseases are transmitted by vectors such as insects (mosquitoes, lice, ticks) or rodents. These vector organisms are sensitive to climatic conditions, especially temperature and humidity. Thus, the distribution of vector-borne diseases is restricted by the climatic tolerance limits of their vectors. Further, biological restrictions that limit the survival of the infective agent in the vector population also determine the limits for disease transmission. Human activities also restrict disease transmission both directly, e.g. reducing vector populations by spraying, and indirectly, e.g. by introducing agricultural practices unfavourable to the local vector.

Climate plays a dominant role in determining the distribution and abundance of insects and tick species, either directly or indirectly through its effects on host plants and animals. Therefore, it is anticipated that climate change will have a significant effect on the geographical range and seasonal activity of many vector species (McMichael *et al.*, 1996b). This sensitivity is reduced, however, if the vector is adapted to an urban or domestic environment. In addition, land use change is also likely to be the major factor in future changes in vector distribution and abundance in Europe.

The effect of climate change on actual human cases of disease is much harder to forecast than changes in the distribution of the vectors. The life-cycle stages of the infecting parasite within the vector are also limited by temperature. There is often minimum temperature for completion of the extrinsic incubation period and this is a limiting factor for transmission in many temperate areas. These limits will expand north with climate change.

The current main vector-borne diseases in Europe can be classified as:

- Formerly widespread, e.g. malaria - actually endemic in some European countries, such as Turkey, Azerbaijan, Tajikistan.
- Locally endemic, e.g. leishmaniasis- southern France, Italy, Spain, Portugal; Tick-borne encephalitis - Southern Scandinavia, Central and Eastern Europe.
- Emergent diseases, e.g. Lyme disease - prevalent over much of Europe.

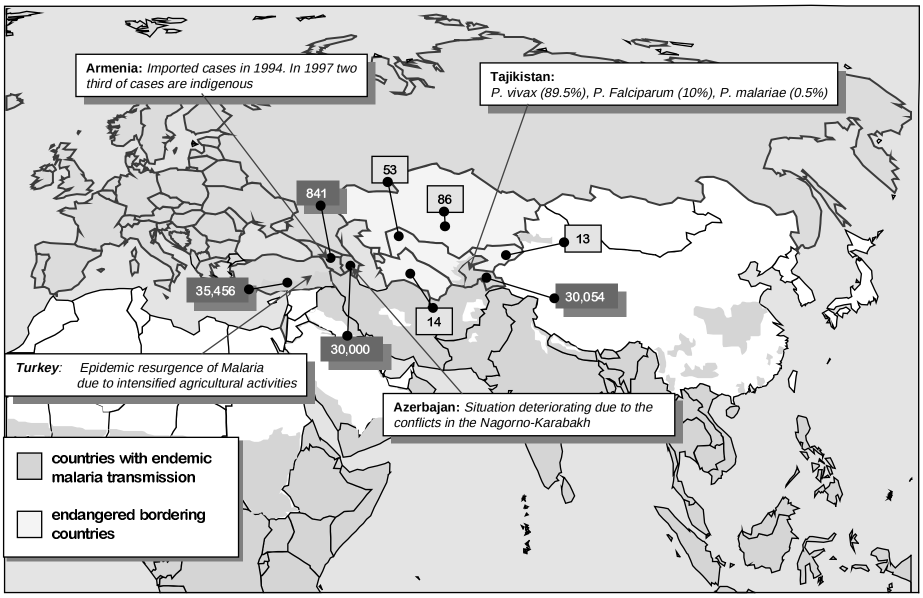
These diseases are addressed in more detail below.

3.7.1 *Malaria*

Malaria is the most important vector-borne disease worldwide. Malaria has, in recent years, also become a growing problem in Europe. Three out of the fifty countries in the World Health Organization European Region, are currently endemic for malaria: Azerbaijan, Tajikistan and Turkey. In 1994, the population in these countries was estimated at 75 million and a total of 88.313 cases of malaria (passive case detection) were reported. A recent assessment in Tajikistan found that the incidence of malaria was 22 per 1.000 population and in one district approximately 15% of this cases were caused by *P. falciparum* (Pitt *et al.*, 1998). This incidence rate is 10 times that reported using routine/passive surveillance. In Turkey, *P. vivax* malaria is resurgent after the disease was controlled in the 1960s. Since the late 1970s, malaria increased to epidemic proportions in the South East Anatolia area, bordering Iraq, from population movements, civil instability and the importation of malaria cases from neighbouring endemic countries.

There have been recent reports of local transmission in Turkmenistan, Uzbekistan and the Urals, which is thought to have originated from imported cases from nearby Afghanistan, Tajikistan or Azerbaijan (Nikolaeva, 1996). It is likely that malaria importation into the NIS has occurred as a result of war in Afghanistan and Azerbaijan and the associated population movements across national borders.

Figure 8: Resurgence of Malaria in the WHO European Region (1997)



Armenia: *Imported cases in 1994. In 1997 two third of cases are indigenous*

Tajikistan: *P. vivax (89.5%), P. Falciparum (10%), P. malariae (0.5%)*

Turkey: *Epidemic resurgence of Malaria due to intensified agricultural activities*

Azerbajan: *Situation deteriorating due to the conflicts in the Nagorno-Karabakh*

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Figure 9: Imported Malaria cases in Europe, rates per 100.000 in 1997

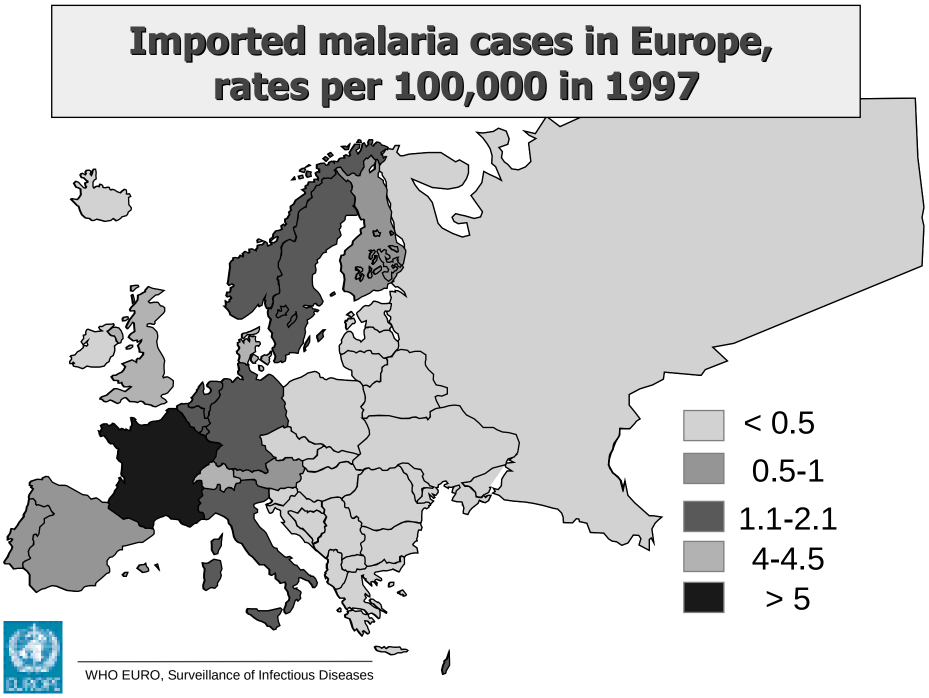


Table 8. Resurgence of malaria in countries of the former Soviet Union and Turkey

Country	**Year**	**Total cases**	**Local cases**	**Vector**	**Parasite**
Azerbaijan	1996		13135	*An. sacharovi*	*P. vivax*
Tajikistan	1997		21245	*An. sacharovi*	*P. vivax P. falciparum*
Turkmenistan	1983 - 1992	188	44	*An. sacharovi*	*P. vivax*
Urals	1996	12	2	*An. messae*	*P. vivax*
Uzbekistan	1983-1992	755	39	*An. sacharovi*	*P. vivax*
Turkey	1994	84345	?	*An. sacharovi*	*P. vivax*

Source: Nicolaeva, personal communication, WHO - ECEH, 1998a

Governments were unable to afford insecticides and manage appropriate vector control programmes. Consequently, mosquito densities increased and enhanced the probability of local malaria transmission of imported parasite strains. There is now a risk that malaria may be introduced to surrounding countries where potential malaria vectors are present. The importation of cases into Bulgaria and Romania from the NIS is now increasing, and this increases the risk of local transmission. This risk of the re-introduction of malaria to Eastern Europe can be increased by climate change.

Concomitant with increases in the volume of international travel, all countries in Europe have seen a steady increase in the number of imported cases of malaria. It has been estimated that, in the period 1985-1989, 16.000 European travellers were infected with malaria, but this number is likely to be an underestimate (WHO, 1997). In 1994, 17 malaria deaths in travellers were recorded.

Data from the United Kingdom Malaria Reference Laboratory (PHLS, 1998) show that cases of imported malaria have risen from 66 in 1966 to 2.500 cases in 1996 - nearly a 40-fold increase some of which is explained by the increase in the volume of international travel. The majority of imported cases originated in Africa. Most imported cases are from *P.vivax*, however, prevalence of imported *P. falciparum* increased by some 15% during 1977-1986 in the United Kingdom (Jetten and Takken, 1994). Since 1988, P. falciparum accounts for more than half the cases (PHLS, 1998). In 1997, a rise in cases imported from East Africa was noted from the malaria epidemics triggered by heavy rains in Kenya and Uganda. Other European countries with imported malaria are France; Germany, and Italy.

Airport malaria occurs when vectors that have arrived on aircraft infect people. People who work and live in or near airports are most at risk. Since 1969, 63 cases of airport malaria have been reported in Western Europe and most were caused by *P. falciparum*. Some tropical vectors can survive in the low temperatures of a luggage compartment and are therefore ideal for overseas transportation. For example, *Anopheles arabiensis* from Madagascar overwinters in altitudes above 1.500 m (Castelli *et al.*, 1994). Six cases of airport malaria were described in and around the main airport in Paris, France, during the very hot summer of 1994 (Guillet *et al.*, 1998). Consequently, aircrafts are now sprayed regularly with residual pyrethroids.

The six major vectors of European malaria, *An. atroparvus*, *An. labranchiae*, *An. maculipennis*, *An. messae*, *An. sacharovi* and *A. superpictus* are distributed throughout the continent (see Table 9). Jetten and Takken (1994) have reviewed the published data on vector distribution, but it is likely that much of these are out of date. There is a need to map the current distribution of malaria vectors in Europe.

Table 9. Current distributions of mosquito species in Europe which are known to transmit malaria

Vector	**Distribution**
An. atroparvus	South east coast of Sweden, Ireland, south of Britain, Denmark, Netherlands, Belgium, Germany, Poland, France, Hungary, Romania, Bulgaria, Portugal, Spain, northern and inland Italy, former Yugoslavia, south western Russia, coast of the Black Sea.
An. labranchiae	South east of Spain, Corsica, Sardinia, Sicily, coasts of Italy, Malta, Dalmatic coast of Yugoslavia.
An. maculipennis	Norway, south and central Sweden, Britain, Netherlands, Belgium, Germany, Poland, France, Switzerland, Austria, Czechoslovakia, Hungary, Romania, Bulgaria, Portugal, Spain, Italy, Albania, former Yugoslavia, Greece, Cyprus, western Russia, Turkey.
An. messae	Sweden, Finland, Denmark, Ireland, Britain, Netherlands, Belgium, Germany, Poland, France, Austria, Czechoslovakia, Hungary, Romania, Bulgaria, Corsica, north Italy, Albania, Greece (Macedonia), former Yugoslavia, Siberia, Urals.
An. sacharovi	Albanian coasts, former Yugoslavia, Greece, Romania (Black Sea shores), Bulgaria, Cyprus, coasts of Turkey, Azerbaijan, Turkmenistan
An. superpictus	Sicily, Italy, Romania, southern Bulgaria, Albania, Dalmatic coast of Yugoslavia, Yugoslavian Macedonia, Kosovo, Greece, Cyprus, Turkey.

Source: Jetten and Takken, 1994;

Transmission have been reported from Greece, Italy, Spain and Portugal (Jetten and Takken, 1994). The population of *An. labranchiae* has recently increased in Italy from large-scale rice cultivation. Abundance of *An. messae* has increased in the Russian Federation (Russian Plains, lower Volga, Crimea and the Urals) from environmental changes such as increases in overgrown lakes and ponds together with warmer springs. Consequently, local transmission of *P. vivax* malaria has occurred in these regions (Nikolaeva *et al.*, 1996).

Introduced, indigenous, or autochthonous malaria is defined as an infection transmitted by a local Anopheles mosquito in a country, which has achieved eradication (Holvoet *et al.*, 1983). This is only possible when the following conditions are fulfilled:

- a sufficient density of local *Anopheles* mosquitoes;
- a sufficient incidence of imported malaria;
- compatibility between the local vectors and the imported *Plasmodium* strain;
- optimal climatic factors allowing a complete sporogonic cycle in the vector.

Malaria was successfully eradicated from most of Europe during the 1950s and the 60s. The resurgence of malaria in Eastern Europe is now a major cause for concern. In Western Europe, several cases of local transmission also have been reported. In Corsica in 1970-71, imported *P. vivax* caused an autochthonous outbreak of malaria, which infected both tourists and locals (Holvoet *et al.*, 1983). In 1997, a woman with no travel or blood transfusion history who lived at a great distance from the nearest airport was diagnosed with *P. vivax* in Maremma, Italy. Investigations revealed that the parasite had been transmitted by *An. labranchiae*, the previous vector of malaria in Italy. The vector had acquired the parasite from a neighbour infected with *P. vivax* during a trip to India (Balderi *et al.*, 1998). This case illustrates the ease with which malaria can be transmitted in areas when the above conditions are fulfilled.

There is a concern that imported cases may cause the reintroduction of falciparum malaria in Europe. Some local mosquitoes were clearly once vectors of the European strain of *P. falciparum*, but it is not known if they also are capable of transmitting its tropical strains. It has been shown that *An. atroparvus*, *An. messae, An. sacharovi* and *An. labranchiae* are refractory to strains of *P. falciparum* from Kenya, Malaya and India (Marchant *et al.*, 1998; Daskova and Rasnicyn, 1982; de Zulueta *et al.*, 1975; Ramsdale and Coluzzi, 1975). However, the suspected vector of malaria in the United Kingdom, *An. plumbeus* has been infected with *P. falciparum,* but it is not yet clear that the mosquito is able to transmit the parasite (Marchant *et al.*, 1998). These studies therefore suggest that, in general, European vectors of malaria are not able to transmit tropical falciparum malaria. Only after a long period of selection would the tropical parasites become adapted to transmission by *Anopheles* in Europe.

The risk of re-introduction of vivax malaria in western and central Europe must be addressed. *P. vivax* is present in eastern Europe and has been responsible for recent local cases (described above). The vectors *An. atroparvus, An. sacharovi* and *An. messae* are susceptible to *P. vivax* from Africa, Asia and South America (Daskova and Rasnicyn, 1982). There is a risk that *P. vivax* is homogeneous in its adaptation to vectors. This would mean that the parasite could be imported from any endemic country.

3.7.2. Leishmaniasis

Leishmaniasis occurs in two forms both of which are present in Europe (Desjeux, 1991). The cutaneous form is caused by *Leishmania infantum*. Cutaneous leishmaniasis (CL) cases have been reported from Italy, Spain, France and countries in Central Asia. Visceral leishmaniasis is also caused by *L. infantum*. Zoonotic visceral leishmaniasis (ZVL)(also known as kala azar) is endemic in all countries bordering the Mediterranean. It has become an important co-infection with HIV in in Spain, France and Italy (Dedet *et al.*, 1995).

Leishmaniasis is transmitted by sandflies, which inhabit semi-arid regions. Sandflies are very susceptible to DDT. P and were significantly reduced in Europe following malaria eradication campaigns in the 1960s and 70s. However, as vector control declined, vector densities have increased. The reservoir or intermediate host of the pathogen are rodents, foxes and domestic or stray dogs. In urban endemic areas, the black rat may play a role in transmission.

There are two sandfly vectors of Leishmaniasis in Europe. *Phlebotomus perniciosus* is distributed throughout the Mediterranean (France, Portugal, Spain, Tunisia, and Turkey). *Ph. perfiliewi* is the suspected vector of cutaneous leishmaniasis. It has more a northern distribution, extending from Greece, Cyprus, Malta (but not North Africa) to Eastern Europe (Hungary, Romania, Yugoslavia, and Azerbaijan).

Sandfly vectors are not actively controlled in Europe. CL and ZVL are controlled by the treatment of human cases. In Europe, canine leishmaniasis is a major veterinary problem and a dog vaccine is considered highly desirable. A vaccine is currently being developed for humans.

It is likely that the distribution of ZVL in Europe is limited by the distribution of the sandfly vectors. Climate change is likely to expand the distribution of the sandfly vectors north. One study on Leishmaniasis in Italy indicates that climate change may expand the range of *Ph. Perniciosus*, but decrease the range of *Ph. perfiliewi* (Kuhn, 1997). Higher temperatures would accelerate the maturation of the protozoal parasite, thereby increasing the risk of infection (Rioux *et al.*, 1985). An important vector in Southwest Asia (including Israel), *Ph. papatasi*, has been mapped using climate and satellite data (Cross *et al.*, 1996). It was estimated that a 3°C rise in temperature would greatly increase both the geographic and seasonal distribution of *Ph. papatasi* in this region (Cross and Hyams, 1996).

There is a risk that ZVL will extend further north in Europe with climate warming. Several imported cases of canine leishmaniasis are reported in Germany, Switzerland, and Austria every year (Gothe *et al.*, 1997). Thus, imported cases are a potential source of the pathogen, if the vectors expand north with climate change.

3.7.3 Dengue

Dengue is the most important human arboviral disease. Dengue and the related syndromes of dengue haemorrhagic fever and dengue shock syndrome are a leading cause of child mortality in Asia. The incidence and geographical distribution of dengue have increased dramatically since the late 1950's and in particular over the last decade. This has been from the combined effects of several factors: unprecedented population growth and unplanned and uncontrolled urbanisation producing a large at-risk population; increased air travel resulting in rapid spread of dengue viruses to new areas by the movement of infected people; and a lack of effective control against vector *Aedes aegypti* mosquitoes that have flourished under these conditions (Rigau-Pérez *et al.*, 1998). *Ae. albopictus* has been successfully introduced to areas where it was never present before.

Currently, dengue is not present in Europe although historically it has been present. In the last part of the 1800s up until 1948, dengue was reported from the following countries in the Eastern Mediterranean: Crete, Greece, Turkey, Lebanon, Palestine, Syria and Egypt (Gratz and Knudsen, 1996). In the last decade, cases have been reported from Saudi Arabia, Djibouti and possibly Yemen. Dengue is included in this report because there is a risk it may be re-introduced into Europe.

The principal vector of dengue is the mosquito *Aedes aegypti*, which is adapted to urban environments. Historically, *Ae. aegypti* has been recorded in several European and North African countries in the Mediterranean region such as France and Portugal. The distribution of *Ae aegypti* closely follows the 10 °C winter isotherm (WHO, 1989). Currently, *Aedes aegypti* is present in sub-Saharan Africa, and in some Gulf States.

Another dengue vector, *Aedes albopictus*, is currently extending its range in Europe. It was introduced into Italy in 1990, and has been reported from 10 Italian regions and 19 provinces. It has also been separately reported in Albania for several years. The climatological limits to the distribution of *Ae. albopictus* are: winter monthly mean temperature > 0 °C; mean annual rainfall > 50 cm; and mean summer temperature > 20 °C. Countries in Europe where current climatic conditions meet such criteria include Spain, Portugal, Greece, Turkey, France, Albania, and the Republic of Yugoslavia (Knudsen *et al.*, 1996).

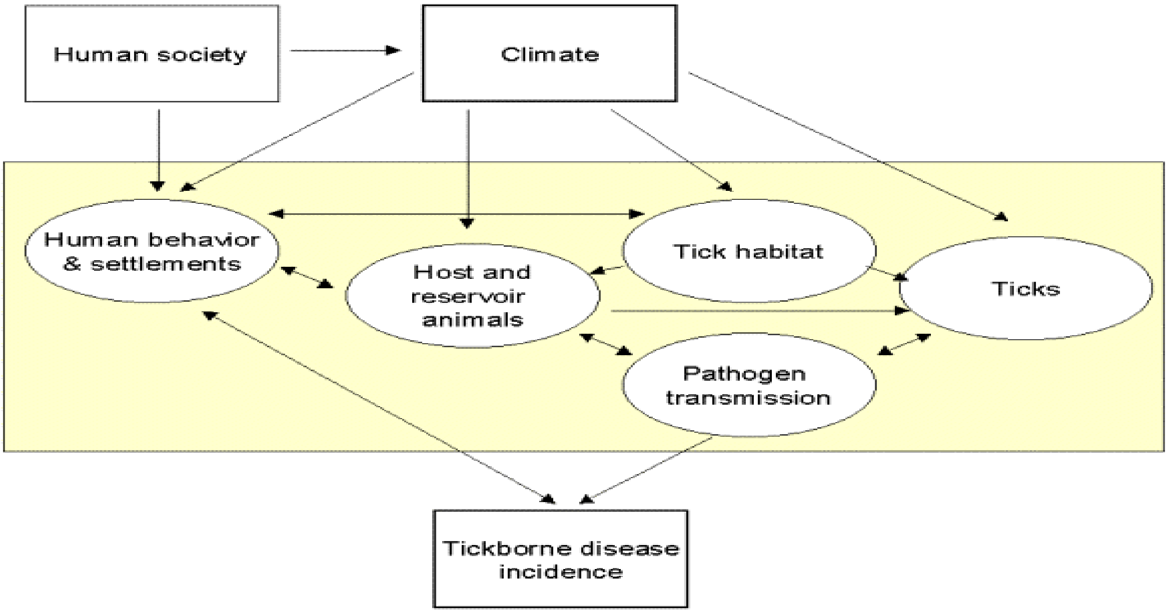
Epidemiological studies have shown that temperature is a major factor in urban dengue transmission (reviewed by McMichael *et al.*, 1996b). A 2° C increase in global mean temperature by 2100 can potentially increase the latitudinal and altitudinal range of transmission of the disease. In temperate locations, climate change would increase the length of the transmission season (Jetten and Focks, 1997).

A mathematical model of dengue transmission has been developed and validated by Focks *et al.*(1995). The model indicates that dengue transmission could occur in Athens, Greece, for a short period in late summer under current climate conditions, if vector and virus were introduced (Jetten and Focks, 1997). This is consistent with observed transmission as Athens experienced a large outbreak of dengue in 1928. Under an arbitrary climate change scenario (a 2 °C increase in global mean temperature by 2100) seasonal dengue transmission could occur in southern and central Europe, if the vector were to be established.

3.7.4 Tick-borne diseases

Ticks transmit several bacterial, rickettsial and viral pathogens to humans. Ticks are ectoparasites and their geographical distribution depends upon the availability of suitable habitat vegetation and host species, usually rodents, large mammals, such as deer. The distribution and population density of ticks is also limited by climatic factors. Tick vectors are long-lived and are active in the spring-summer-early autumn months. Temperature must be sufficiently high for completion of the tick's life cycle during the warmer part of the year (i.e. above 5-8°C), and high enough in winter to suspend the life cycle. Humidity must be sufficient to prevent both eggs and ticks from drying out. Higher temperatures enhance proliferation of the infectious agent within the ticks, although temperatures above the optimum range reduce the survival rate of both ticks and parasites.

Figure 10: Interactions between tick-borne disease and the environment



Source: Lindgren, 1998

The northern limit of the distribution of ticks in Sweden has changed between 1980 and 1994 (Tälleklint and Jaenson, 1998). In regions where ticks were prevalent in 1980s, population density has increased between the early 1980s and mid 1990s. Unpublished data show that changes in distribution and density over time are correlated with changes in seasonal daily minimum temperatures (Lindgren *et al.*, 1999).

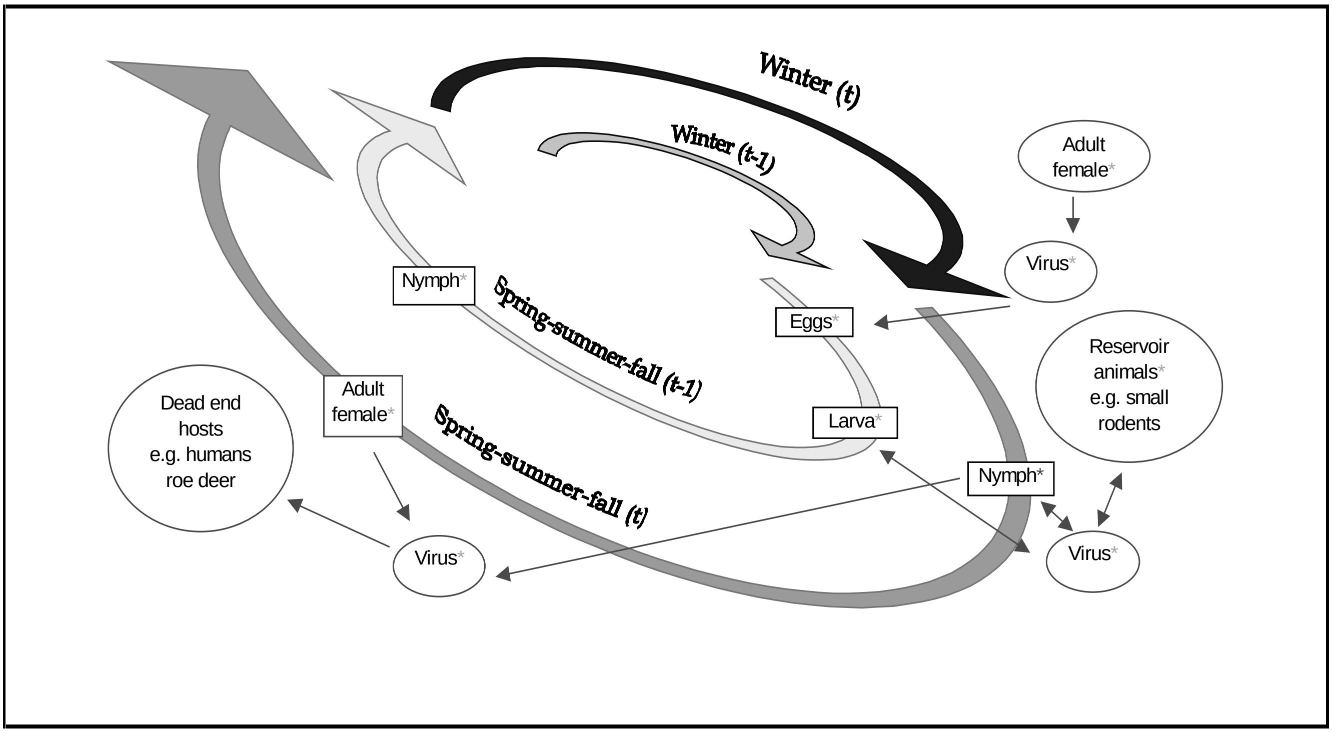
Ixodid ticks such as Ixodes ricinus and I. persulcatus, which are widely distributed in temperate regions, transmit tick-borne diseases in Europe. People most at risk of infection are those who spend time in the countryside or come into contact with the ticks in vegetation in periurban areas. People have also been infected in city parks. Tick populations are difficult to control directly using pesticides. It is also difficult to control the host animal populations due to the diversity of species that can provide ticks with a blood meal. Tick populations may be controlled indirectly by modifying the local vegetation type but this can only be done on a small scale. Currently, the most effective public health measure is to raise public awareness about tick-borne diseases and how to avoid infection. A vaccine for Lyme borreliosis has recently been developed in the US but this would not be applicable to Europe, due to more heteorogenous pathogen structures. A vaccine for Tick borne encephalitis (TBE) is available and persons at high risk of infection (e.g. those who live or work in endemic areas) are vaccinated in Sweden and other countries.

Lyme Borreliosis or Lyme disease is prevalent over much of Europe. The disease agent was described in 1975 after an outbreak in the US and the disease is therefore considered as an emerging infection. It is now the most prevalent arthropod-borne disease in temperate climate zones. Increase in disease incidence has been observed in several European countries (e.g. Sweden, Finland, Slovenia, the Russian Federation, Germany and Scotland). This may partly be due to increased reporting, as well as a real trend. For example, an increase in Lyme disease during the last decade has been serologically confirmed in Sweden (Berglund *et al.*, 1995).

The risk of contracting the pathogen, *Borrelia burgdorferi*, from a single tick bite is 1 in 100-150 in endemic regions (Gustafson, 1994). Lyme Borreliosis is a complex multi-system disorder and includes cardiac and neurological disorders and arthritis. Most infections are asymptomatic and self-limiting, but the disease can be fatal if left untreated. Transmission occurs during the spring-summer-early autumn months when the ticks are active. Climate warming is likely to lengthen this transmission period.

TBE is present in southern Scandinavia, central and Eastern Europe. There are at least two distinct types: the central European form of tick-borne encephalitis which was first identified in the 1930s; and the Russian spring-summer encephalitis subtype which encompasses several diseases world-wide including Omsk haemorrhagic fever in Siberia. The risk of contracting the disease from a single tick bite is 1 in 600 in endemic regions (Gustafson, 1994). The mortality rate for TBE is 1% and 10% of cases lead to permanent paralysis. Mortality rates are higher for the Russian spring-summer encephalitis subtype.

Figure 11: Schematic overview of a 2-year tick lifecycle in relation to the transmission of Tick born encephalitis.



Source: Lindgren, 1998

TBE virus is transferred mainly from small rodents to humans by ticks. The virus has been shown to infect humans via unpasteurised goat milk as well, which has lead to some rare localised outbreaks in Eastern Europe. A study of TBE during nearly 4 decades in a highly-endemic region in Sweden found that TBE incidence increased after milder winters (i.e. less days with temperatures below –7°C) in combination with extended spring and autumn seasons during two successive years (Lindgren, 1998). It is therefore likely that climate change could extend the length of the transmission season for tick-borne diseases in central, eastern and northern Europe and facilitate the spread of the disease to higher latitudes and altitudes.

3.8 Rodent-borne diseases

Rodents are reservoirs for a number of human diseases. Rodents can act as both intermediate infected hosts or as hosts for arthropod vectors such as fleas and ticks. Rodent populations are affected by weather conditions. In particular, warm, wet winters and spring increase rodent populations. Under climate change, rodent populations could be anticipated to increase in temperate zones, resulting in greater interaction between humans and rodents, and a higher risk of disease transmission, particularly in urban areas. Rat populations have increased significantly in recent years. In some European countries such as the United Kingdom, breakdown in sanitation controls and inadequate hygiene is contributing to serious problems with rat infestations (Meyer and Shankster, 1994).

Hantaviruses and their rodent hosts are present in Europe and cause haemorrhagic disease. Haemorrhagic fever with renal syndrome (HFRS) is a major problem in the Balkans. An outbreak of more than 20.000 cases of HFRS in western Russia was caused by Puumala strain (Bonn, 1998). In Finland, studies have shown that the number of human cases is linked with the host vole population density, which cycles every 3-4 years.

Rats are carriers of *Leptospirosa interrogans*, the agent for leptospirosis or Weil’s disease. Human infections occur after direct contact with soil or water contaminated with rat urine or faeces. Thus, flooding increases the risk of human infection.

3.9 Pest species

Many organisms, which are considered pests, are involved in the transmission of infectious diseases in Europe. However, information about the potential response of these species to climate change is very incomplete.

Higher mean temperatures and damp winters arising from climate change may increase fly (*Musca*) and blowfly (*Calliphora*) populations. Populations of other fly species may also increase, particularly given the trend towards more intensive animal farming, which produces large quantities of manure. All species in these groups are capable of breeding at temperatures of 10 °C, and larvae will continue to develop at a temperature as low as 3.5 °C. Thus, if temperatures rise, contamination of food with enterobacteria or enterovirus could increase and become prevalent for a greater part of each year.

In common with flies, cockroaches (*Blattidae*) are potential "mechanical" carriers of foodborne pathogens and considered to be major hygienic pests of the domestic environment. In Europe, higher temperatures might encourage cockroaches to venture from the domestic environment and into sewers. Higher temperatures would also facilitate passage of cockroaches and other insects between dwellings, making control of infestations more difficult (Alexander, Newton and Crowe, 1991).

3.10 Impacts on food supply

During the past 10.000 years of the current Holocene period — which have been relatively stable in climatic terms — farming methods have been evolving and improving, enabling more food to be produced. Local climatic limitations on crop growth have been overcome through irrigation, fertilisation, mechanisation, and the breeding of varieties adapted to local conditions. During the past fifty years, the food requirements of a rapidly expanding population, combined with the world-wide shortage of new tracts of arable land, have placed an unprecedented reliance on yield improvement.

Climate change could affect food production in several ways:

- geographic shifts and yield changes in agriculture;
- reduction in the quantity of water available for irrigation;
- loss of land through sea level rise and associated salinisation;
- impacts upon fisheries productivity through sea level rise, and changes in water temperatures, currents, freshwater flows and nutrient circulation.

Predicting the impacts of climate change upon crop and livestock yields is a complex task. Agricultural production is sensitive to the direct effects of climate, particularly extreme weather events. It is also sensitive to the indirect effects of climate on soil quality, the incidence of plant diseases, and on weed and insect (including pest) populations. In particular, irrigated agriculture would be affected by changes in the water resources. Assessments of the impact of climate change upon agricultural productivity have been reviewed by the IPCC (Reilly *et al.*, 1996).

In general, the modelling exercises reported to date have not attempted to incorporate social and economic responses. However, it is assumed that farmers will adapt to changes in climate, for example, by changing crop varieties or dates of planting. Human societies would clearly respond to significant changes in food supplies, for example, by migration. The complex political, economic and technological influences upon world food production are difficult to quantify. These influences include those rapid commercial and political changes that have encouraged the production of standardised crops for unseen, remote markets using large-scale, heavily mechanised agricultural production methods, to the extent that food has gradually become an international commodity rather than a source of nutrition for local populations.

In Europe, the regional assessment by the IPCC concludes that crop mixes and production zones will be redistributed (Beniston and Tol, 1998). Subsequent changes in food prices are highly dependent on world markets and adaptive actions taken by producers. Relatively few studies, however, have addressed hunger vulnerability in Europe, and vulnerable groups are not identified in the IPCC assessment. Several regional assessments for Europe have also been undertaken (e.g. Harrison et al., 1995; CLIVARA, see also Table 2). These studies focus on model simulations for changes in crop yield and agricultural risk.

The political implications of climate change must also be considered. As land areas suitable for cultivation of key staple crops or productive fishing grounds undergo geographic shifts in response to climate change, they may become the subject of political conflict. Conflicting demands for water may also cause problems, particularly in Turkey, Israel and other semi-arid countries (Thysson and Bartram, 1999).

4. Health impacts of stratospheric ozone depletion

The amount of ultraviolet radiation (UVR) that may reach a given part of Earth's surface at any time, is determined by a great variety of factors, including latitude, the seasons of the year, the time of the day, altitude, local atmospheric conditions (smog, cloudiness, haze, smoke, dust, fog, altitude, aerosol particles), variations in the ozone layer thickness, and height of the sun above the horizon. UV radiation may damage the skin and the eyes and have influence on the immune system (see Table 10). The effects of UV radiation on the skin can be acute or chronic. The acute effects are erythema and sun burn meanwhile the chronic effects can be freckles, and solar lentigines, melanocytic nevae, solar keratosis, photoageing and cancer (WHO, 1994). We report in this document only skin cancer, the effects on the eyes and immune system.

Table 10. Summary of the main effects of solar ultraviolet radiation on the health of human beings

Nature of effect	Direction of effect	Strength of evidence
Effect on immunity and infection		
Suppression of cell-mediated immunity	Harmful(?)	Sufficient
Increased susceptibility to infection	Harmful	Sufficient
Impairment of prophylactic immunization	Harmful	Inadequate
Activation of latent virus infections	Harmful	Sufficient
Effects on the eye		
Acute photokeratitis and photoconjunctivitis	Harmful	Sufficient
Climatic droplet keratopathy	Harmful	Limited
Pterygium	Harmful	Limited
Cancer of the conjunctiva	Harmful	Inadequate
Lens opacity (cataract)	Harmful	Limited
Uveal melanoma	Harmful	Limited
Acute solar retinopathy	Harmful	Sufficient (?)
Macular degeneration	Harmful	Inadequate
Effects on the skin		
Malignant melanoma	Harmful	Sufficient
Non-melanocytic skin cancer	Harmful	Sufficient
Unburn	Harmful	Sufficient
Chronic sun damage	Harmful	Variable
Photodermatoses	Harmful	Sufficient
Other direct effects		
Vitamin D production	Beneficial	Sufficient
Other cancers	Beneficial	Inadequate
General well-being	Beneficial	Inadequate
Indirect effects		
Effects on climate, food supply, disease vectors, air pollution, etc.	Probably harmful	Inadequate

Source: Armstrong, 1994 adjusted by van Loveren, personal communication, 1999

4.1 *Skin cancer*

Many epidemiological studies have implicated solar radiation as a cause of skin cancer (both melanotic (MM) and non-melanotic (NMSC)) in fair-skinned humans (IARC, 1992; WHO 1994a). Non-melanotic skin cancers are of two major histological types: basal cell carcinoma and squamous cell carcinoma. The risk of these cancers has generally been thought to correlate with cumulative lifetime exposure to solar radiation. But recent evidence suggests that the relationship is more complex - at least for basal cell carcinoma, for which it appears that childhood exposure may be important (Vitasa, 1990; Kricker , 1995; Moan and Dahlback, 1992). These cancers usually develop on parts of the body most often exposed to sunlight (e.g. face, neck, scalp, hands and arms) (Czarnecki, 1991; Kricker, 1994)

Malignant melanoma, a cancer of the pigment-producing cells of the skin, usually develops on an already pigmented patch such as a mole. (Philipp *et al.*,1983, 1984, 1987). The relationship between melanoma skin cancer and UVR is complex. Overall, 60-90% of melanomas in fair-skinned populations are estimated to involve sunlight exposure (Armstrong and Kricker, 1993). Repeated severe sunburn episodes in early life are considered important for the development of melanoma. The incidence of melanoma in white populations has risen by 3-7% every year since at least the 1960s, and probably reflects a progressive increase in average levels of personal exposure to solar radiation, owing to changes in patterns of recreation, clothing and occupation that are unrelated to stratospheric ozone depletion (Armstrong and Kricker, 1994).

Estimates have been made of how ozone depletion may affect the rate of skin cancer in certain countries. The model developed by Slaper and colleagues (1996) takes into account the production and emission of ozone-depleting substances, the global stratospheric chlorine concentrations, local depletion of stratospheric ozone, the resulting increases in UV-B levels, and finally, the effects on skin cancer rates. Several delay mechanisms in the effect of ozone depletion on skin cancer rates are important, such as tumour development. In the case of ozone depletion, the separate scenarios modelled related to the Montreal Protocol, the international agreement, which restricts the production of ozone - depleting substances. Thus, full compliance with the Montreal Protocol and all its amendments and adjustments, would lead to a peak in stratospheric chlorine concentration and ozone depletion around 2000 (see Figure 6), and to a peak in skin cancer by about 2050. The latter delay is mainly because of the fact that skin cancer incidence depends on the cumulative UV-B exposure.

In the most recent assessment by UNEP (19989 the above projections for total skin cancer for a "European" population living around 45 degrees North have been updated. UNEP estimates that, under the amended Montreal Protocol, there will be an excess incidence peaking at around 5% during the third quarter of the coming century. This means extra 100 cases of skin cancer per million populations per year from stratospheric ozone depletion. The current background rate of skin cancer is approximately 2.000 cases of skin cancer per million populations per year. If the moderate ageing of the "European" population were factored into the modelling, the excess incidence would become, proportionally, a little higher. The UNEP calculations assume that behavioural and demographic risk factors do not change and that current ozone depletion rate and UVR exposure increases are sustained during the next several decades.

4.2 UVR and damage to the eye

The external epithelial layer of the eye, the cornea and conjunctiva, absorbs virtually all UVR with a wavelength of less than 290 nm. Excessive exposure to UVR is known to cause damage to the eye's outer tissue. The conditions most directly linked to UVR exposure are corneal photokeratitis ("snow blindness"). This is caused by acute exposures and is the ocular equivalent of sunburn. Chronic exposure to UVR is linked to conditions such as pterygium (WHO, 1994b). The role of UV-B in cataract formation is complex and unclear. Some cataract subtypes are associated with UVR exposure, but others are not.

4.3 UVR and the immune system

There is good evidence both in humans and experimental animals that UVR causes local (i.e. occurring only at the site of irradiation) and systemic immunosuppression. Although the mechanisms of UVR-induced immunosuppression are better understood, many questions remain to be answered. The consequences of immunosuppression for patterns of infectious disease in human populations are less clear.

Cellular immunity and natural killer activity have been shown to be affected by ambient doses of UVR (Garssen *et al.*, 1998). Therefore, UV-induced suppression may play a role in reduced resistance to skin tumours. Immunosuppression may also lead to diminished resistance to viral and bacterial infections, because, in addition to natural killer activity and cellular immunity, phagocytic activity is also reduced. All these mechanisms are involved in immunological resistance to infections. Such effects have been shown in experimental laboratory animals. Animal data can be extrapolated to humans with information from species comparison studies. The results from such extrapolation studies indicate that ambient doses of UVR reduce resistance to infectious diseases in humans (Goettsch *et al.*, 1998). The effect of UVR on herpes simplex infection is well - known and confirms the effects found in animal studies.

Further epidemiological studies are required to fully understand the impact on incidence and prevalence of infections. It should be noted that even a modest effect on the immune system that may result in a moderate depression of resistance to an infection, or affect the duration or severity thereof, may have a significant aggregate social and economic impact at the population level in the case of very common diseases (such as the common cold and gastro-enteritis).

UVR-induced changes in immune response may also affect autoimmune diseases. Increases in UVR may either suppress or aggravate the disease depending on the type of immune response that underlies the pathology. It has recently been proposed that increased UVR exposure is associated with decreased occurrence of multiple sclerosis on the basis of epidemiological and laboratory evidence (McMichael and Hall, 1997). It is also known that UVR aggravates lupus lesions when used as a medical treatment (UNEP, 1998).

It is now generally accepted that allergic respiratory disease (e.g. asthma) is associated with the enhanced expression of the Th2 pathway immune response (Cookson and Moffat, 1997). UVR has been shown to preferentially suppress the Th1 component of the cellular immune response and enhance the Th2 component. It has also been suggested that production of IgE - the immunoglobulin involved in the immediate hypersensitivity immune (allergic) response - is stimulated by UVR in experimental animals (Garssen *et al.*, 1998; Selgrade *et al.*, 1997). The detrimental effect of UVR on lupus, which is a Th2 type phenomenon, supports the argument for this mechanism in humans. The stimulation of Th2 response by UVR, and hence stimulation of IgE production, may result in respiratory allergy. Therefore, increased UV exposure, e.g. from lifestyle and personal behaviour, may have a role in the as yet unexplained increase in the prevalence of respiratory allergy in many countries.

An increase in UV radiation, by affecting the immune system, may have important impacts on the incidence and prevalence of infectious diseases. It may also have important impacts on autoimmune and atopic diseases. It should be noted that climate change may also have an effect on the distribution of pathogens and allergens, as well as other factors that affect the immune system such as natural toxins from moulds that contaminate wheat. Such phenomena may well interfere with and influence the consequences of immunosuppression.

5. Early effects of climate change on human health

The detection and attribution of early impacts of climate change on human population health is a priority. A range of anticipated health impacts from climate change and stratospheric ozone depletion has been described. Some of the impacts resulting from the direct-acting effects are likely to become evident within the coming decades. For example, an increase in heatwave-related deaths and an increase in ultraviolet-induced skin cancer in some populations may occur soon or already are occurring.

There is good evidence that anthropogenic climate change is already having an effect on plant growth and distribution (see section 2.2). There is also good evidence of climate-related changes in the distribution and behaviour of animal species both within Europe and elsewhere (BirdLife International/WWF, 1997). A study of Edith's checkerspot butterfly in North America found that the species had extended its range north and reduced its range to the south (Parmesan, 1996). This study also confirmed that the changes were consistent with observed shifts in climatic bands.

At a global level, patterns of changes in human disease are compatible with the advent of climate change. In particular, increases in vector-borne diseases have been observed in highland regions (Epstein *et al.,* 1997). The primary vector of dengue, *Ae. aegypti,* has been reported at above 2.200m in Colombia where it was previously limited to an altitude of 1.500 m. In Mexico too, dengue has recently spread to previously unaffected higher altitudes (Herrera-Basto *et al*., 1992). An analysis of recent historical malaria data in the highland region of Ethiopia demonstrated an increasing trend in malaria mortality and morbidity over the last two decades (Tulu, 1996). Analyses of data over the most recent decade indicate that increases in malaria outbreaks in Ethiopia during the past decade were mainly a result of the observed increase in night-time temperatures. Thus, regional climate change appeared to be the cause of the extension of malaria transmission to higher altitudes, while also increasing the rate and duration of transmission in areas that were previously epidemic-prone (for example, converting a seasonal pattern of malaria to year-round transmission).

The time frame of the emergence of the health impacts of climate change would depend on several factors:

- The "incubation" period (delay between environmental event and onset of ill-health), which ranges from almost zero (storm-induced injury for example), to weeks or months (vector-borne infections); to years and to decades (UV-related malignancies)
- Factors influencing "detectability", given that a change really does occur. The extent and quality of information and variability in the background or pre-existing level of disease must be considered. The time of first detectability of health impacts of climate change will depend on two primary determinants:
    (i) the sensitivity of response (i.e. how steep is the rate of increase);
    (ii) whether there is a threshold that results in a "step function".

It is likely that the first detectable changes will be in the geographic range (latitude and altitude) of certain vector-borne infectious diseases and/or in the seasonality of these diseases. For example, summer-time food-borne infections (e.g. salmonellosis) may show longer-lasting annual peaks.

If extreme weather events become more frequent (e.g. heatwaves, floods, droughts) then detectability will refer principally to whether the frequency of such events or "exposures" has increased. If such events become more, or less, severe, then it would be possible to detect changes in the magnitude of health impacts associated with such events.

Any changes in levels of nutrition and hunger will be difficult to attribute to climate change *per se*. There are many, complex, influences on food production. Temporal trends in production policies, soil degradation, variety of genotypes and phenotypes, along with trends in transport, storage, distribution and marketing, ensure that it remains difficult to discern any influence of climate change upon food production.

Section 6.4 addresses the monitoring and surveillance systems that are need to detect these early impacts of climate change on human health.

6. Actions to reduce the health impacts of climate change

Actions to reduce the health impacts of climate change can be thought of in terms of the classical categorisation of preventive measures in public health (McMichael and Kovats, 1998b):

1. *Primordial prevention* would entail prevention of climate change itself (mitigation).
2. *Primary prevention*: actions taken to prevent the onset of disease from environmental disturbances, in an otherwise unaffected population (e.g. supply bed nets to all members of a population at risk of exposure to encroaching malaria, , early weather watch warning systems).
3. *Secondary prevention*: preventive actions taken in response to early evidence of health impacts (e.g. strengthening disease surveillance; adaptation).
4. *Tertiary prevention*: health-care actions taken to lessen the morbidity or mortality caused by the disease (e.g. improved diagnosis and treatment of cases of malaria).

Secondary and tertiary prevention are both, in general, relatively less effective than primary prevention. They are both ethically and socially undesirable when primary action could be taken.

6.1 Mitigation to reduce or prevent climate change

Mitigation refers to actions that are taken to reduce the emissions or enhance the sinks of greenhouse gases. Mitigation can be achieved in several ways. National and international policies (including those of the EU) centre around the reduction of emissions of greenhouse gases. Few policy measures address strategies to reduce the actual or projected impacts of climate change.

Legal mechanisms now exist for the reduction of greenhouse gas emissions. The United Nations Framework Convention on Climate Change (UNFCCC) came into being at the 1992 UN Conference on Environment and Development (UNCED or the "Rio Summit"). As of October 1998, 176 countries have ratified or accepted the Convention, including the European Union and its 15 Member States. Several countries in eastern Europe have accepted but not ratified the Convention.

The Third session of the Conference of the Parties was held in Kyoto in December 1997. This was the first time that developed country governments committed themselves to legally binding restrictions on emissions. Developed countries that are Parties to the UNFCCC agreed to reduce their emissions of six greenhouse gases, including carbon dioxide, by 5% from the 1990 levels (UNFCCC, 1997a,b). The EU as a whole is committed to reduce emissions by 8%, the Central and Eastern European countries are committed to reductions of 5-8%, while the Russian Federation and Ukraine are committed to stabilise their emissions at 1990 levels.

Some countries have also set voluntary targets for emissions reductions in excess of their obligations under the Conventions. The United Kingdom has set a domestic target of 20% reduction in emissions by 2010. It is clear that global economic mechanisms need to change before effective stabilisation of greenhouse gas concentrations can be achieved. Many countries that have no incentives for legal or voluntary reductions in their emissions also have a supply-driven energy market that is opposed to the use of non-fossil fuel energy sources.

The Fourth Conference of the Parties (COP-4) took place in Buenos Aires, Argentina, in November 1998. The conference objectives were to discuss the implementation of commitments of the Convention that were agreed to at Kyoto. In particular, the Conference aimed to review the adequacy of the commitments and activities implemented jointly (AIJ) (Zwick, 1998).

The long lifetime of greenhouse gases and the latency in the climate system mean that actions taken now will have little effect on future warming before 2050. Further, it is clear that the Kyoto commitments are insufficient to avert serious impacts from climate change. The IPCC anticipates mean global temperature to rise by 1.4 °C by 2050 assuming a standard non-interventionist scenario for greenhouse gas emissions (IPCC, 1996b). About 0.25°C of this warming has already been realised by the 1990s. Parry et all (1998) have estimated that full implementation of the Kyoto targets would reduce the anticipated global warming by only 0.05°C and would not significantly reduce the impacts of climate change on populations at risk of hunger, coastal flooding, or water shortage (see Table 9). This means that governments must take action to adapt to the potential or actual health and other impacts of climate change. Adaptation options are discussed in sections 6.3 and 6.4.

Table 11. Impacts of climate change estimated for the year 2050 under different emission scenarios.

		Additional population at risk due to climate change (millions)		
Emissions scenario	Global warming with respect to 1961-90 (?)	water shortage	coastal flooding	hunger
No mitigation	1.39	1053	23	22
Kyoto targets	1.33	1053	22	20
20% reduction	1.22	909	21	17
30% reduction	1.19	891	20	16

Source: Parry *et al.*, 1998.

Since local emissions of greenhouse gases and ozone-destroying gases contribute to processes of global atmospheric change, preventive policies must be part of a co-ordinated international effort. It is not possible to mitigate on a local or regional basis. European countries, like all other countries, have a moral obligation to contribute to this preventive effort on behalf of human well being and health everywhere. Taking local action to reduce impacts, in the absence of such mitigation attempts, entails an unethical decision to protect local populations when more distant populations may be less able to protect themselves.

6.2 Secondary health benefits of mitigation policies

There is an important opportunity to improve population health in the ongoing negotiations to reduce greenhouse gas emissions. There can be substantial near-term health benefits of many mitigation policies and technologies in Europe and beyond. Two examples of such "no-regrets" or "win-win" policies are listed below. "No- regret" or "win - win" policies reduce greenhouse gas emissions and have other social or environmental benefits:

- Restriction of circulation of private motorised vehicles in urban areas would decrease the burden of mortality and morbidity due to road traffic accidents and reduce pollution
- A significant shift in road transport towards more environmental friendly modes of transport (such as public transport, walking and cycling) would ameliorate air quality and improve population health.

The secondary benefit of the reduction in air pollutant concentrations can be substantial, particularly for the impacts of particulates, nitrogen oxides and sulphur dioxide. The Working Group on Public Health and Fossil Fuel Combustion (1997) estimates the global impact of reduced exposure to particulate matter (PM_{10}) as 700.000 fewer premature deaths per year by 2020 under a mitigation scenario compared to a business-as-usual scenario. This is indicative of the likely magnitude of the health benefits of a mitigation policy scenario.

Cities in China and India have the worst air quality in the world (Ahmed, 1998; WRI, 1998). Greenhouse gas emission reductions in these countries will have a greater health benefit per unit reduction than in those industrial countries where strict controls are already in place. Thus, governments can directly improve health in poorer countries by supporting the use or introduction of climate-friendly technologies. The specific mechanism for this under the UNFCCC is called the "Clean Development Mechanism".

6.3 Adaptation strategies to reduce the potential health impacts of climate change in Europe

Adaptation refers to actions taken to lessen the impacts of the anticipated changes in climate. The ultimate goal of adaptation interventions is the reduction, with the least cost, of diseases, injuries, disabilities, suffering and death from climate change.

Public health programmes should anticipate the health impacts of climate change such as for instance those on infectious diseases. For example, surveillance systems could be improved in sensitive geographic areas. Such areas include those bordering areas of current distribution of vector-borne diseases, and which could themselves experience epidemics under certain climatic conditions. Vaccination programmes could be intensified and pesticides for vector control, and drugs for prophylaxis and treatment could be stockpiled

Clearly, countries in Europe will be able to adapt to some of the health impacts of climate change, either through maintaining existing health and other services, or through new policy measures [see McMichael *et al.*, chapter 15: Human Health chapter. In forthcoming IPCC Special Report on Technology Transfer]. Little is known about the biological or passive adaptation of humans to climate change. Although most assessments of the health impacts of climate change have not addressed adaptation explicitly, assessments of the impacts of thermal stress have modelled the modulating effect of acclimatisation at the population level.

It is also important to remember that, irrespective of climate change, breakdowns in public health measures have been responsible for many recent outbreaks of disease. It is therefore important to stress that climate change presents an additional burden on health. Both existing and future-potential environmental health problems share many of the same underlying causes related to poverty and inequality.

6.4. Monitoring and surveillance

The early impacts of climate change on human population health have not yet been identified. There is therefore an urgent need for systematic assessment of the adequacy of data collection and monitoring systems in relation to this task in Europe and elsewhere (Haines *et al.*, 1993; Haines and McMichael, 1997).

Issues concerning the detection and attribution of the health impacts of climate change were recently discussed at the first interagency workshop on climate change and human health monitoring (sponsored by the World Health Organization, the United Kingdom Medical Research Council and UNEP) (WHO/MRC/UNEP, 1998). The main objectives of the workshop were to set priorities for research and monitoring and to identify opportunities for collecting new data and the integration of both climate and health data. The workshop recommendations include:

- inventory and assessment of relevant climate, environment and health datasets;
- identification of unmet data needs;
- free and easy access to data for research purposes;
- new monitoring initiatives which build on monitoring and surveillance systems and their current strengths.

The Working Group on the Early Health Effects of Climate Change have concluded that there is a need for a more concerted public health approach, starting with the identification of the most appropriate methods for monitoring to detect the early impacts of climate change. Table 12 describes a broad monitoring scheme for the detection of the early impacts of climate change on human health in Europe. Data are needed to provide information for policy makers on the magnitude of climate change impacts. In addition, as part of monitoring systems, such data can help to determine the requirements for and the effectiveness of preventive or adaptive actions. There is an important two-way interplay between research and the development of data collection systems. There is a need to develop indicators of early impacts of climate change. Such indicators need to be climate sensitive, i.e. respond to climate variability on natural scales, of days, weeks, months (seasons) and years.

Table 12. Summary of health impact monitoring needs

Health impact	**Where ?**	**Data needs**
Vector-borne diseases, e.g. malaria, dengue	Margins of distribution both latitude and altitude, e.g. highlands of East Africa for malaria. Areas with sporadic or seasonal epidemics.	Mortality data. Primary care data. Communicable disease surveillance centres. Vector data from local field surveys. Land use/vegetation data (remote sensing) Need for current data sets to be standardized.
Water-borne diseases, e.g. cholera, *Cryptosporidium*.	Current areas of endemicity and sporadic disease.	Mortality data. Communicable disease surveillance data.
Disease related to marine ecosystems, e.g. cholera.	Oceans. Coastal populations.	Disease surveillance, e.g. cholera cases. Sampling of phytoplankton for pathogens, biotoxins, etc. Remote sensing for algal blooms, etc.
Heat-related mortality	Urban populations in developing and developed countries.	Daily mortality and morbidity (chronic cardio-respiratory) data.
Extreme-weather events e.g. floods, storms.	All regions	Mortality data. Disease surveillance, e.g. gastro-intestinal diseases. Data on impacts of disasters.
Sea level rise	Vulnerable populations, e.g. on low lying islands.	Ground water quality. Diarrhoeal disease surveillance.
Malnutrition/Food supply	Critical regions	Population nutritional status. Land use data. Socioeconomic data.

Source: Haines and McMichael, 1997

Currently, continuous monitoring of cause-specific mortality is undertaken in most countries in Europe. However, the data are of variable quality. Infectious disease surveillance varies widely depending on the locality, the country and the disease. The long-term collection of morbidity data and primary care consultation data could give a more sensitive indication of the health effects of climate change (Haines and McMichael, 1997).

It is important to detect early impacts of climate change on heat-related mortality. Comprehensive databases of (daily) all-cause mortality are available in several countries and cities, particularly within the framework of existing European studies on acute effects of air pollution (such as the APHEA database). However, data on cause-specific mortality are less easily available and there are problems with standardisation if one wishes to compare impacts between countries. There is a need to determine if there are time-trends in heatwave-attributable mortality in association with documented background warming.

Table 13 lists the set of priorities and criteria that have been developed to assist in the selection of infectious diseases which should be monitored. Many climate-sensitive diseases are subject to passive surveillance in Europe. WHO-EURO collects surveillance data or some diseases, such as malaria from Member states. European networks for surveillance are already in place for several infectious diseases that may be affected by climate change. These include:

- EWGLI - a network for the surveillance of diseases caused by Legionnella.
- Enter-net - a network for the surveillance of infections caused by *Salmonellas* and also *E. coli* O157.

Table 13. Criteria for monitoring scheme for the early health impact of climate change

Why monitor?	- To detect early effects - To promote better research - To assist in building integrated assessment models - To improve and evaluate adaptation strategies - To inform policy-makers and the public
What should we monitor?	- Climate-sensitive diseases - Potential confounders (migration, life-styles, land-use, etc.) - Adaptation strategies
What criteria do we use to select the climate sensitive diseases?	- Strength of evidence/climate sensitivity - Potential magnitude of effect (economic considerations) - Current availability of data including feasibility and cost of collection - Short-term benefit of the monitoring process (for example, uses for other health activities and preventive work)
How should we monitor?	- Minimum data set - Arrangements for exchange/ co-ordination of data

Source: WHO - ECEH, 1998a

Table 14 shows a list of criteria which are essential to decide which diseases would be suitable to monitor.

Table 14. Criteria for selecting potential diseases for climate change surveillance

CRITERION	**Reason for importance**	**Notes**
1. Suitable for continuos surveillance	Need time series for comparison with climate factors	Low frequency infections suitable for detailed outbreak surveillance e.g. legionella
2. Established aetiology	Need to distinguish direct climate effects from other known factors	Aetiology established for most prevalent infections
3. Environmental sources	Infections with strong environmental aetiology most likely to be affected by climate factors such as thermal/ rainfall variation and extreme events e.g. floods and heatwaves	Particularly waterborne diseases and those sensitive to temperature changes
4. Low or no case to case transmission	Strengthens association with environmental exposure	e.g. Malaria, Campylobacter, Tick-borne encephalitis
5. Sustainable	Surveillance unlikely to be considered cost effective for infections that are not routinely measured, or those with low clinical importance; sentinel surveillance methods may be considered	Need to agree surveillance priorities and to examine feasibility of using existing surveillance systems
6. European network already in existence	Increases sustainability	e.g. ENTERNET for Salmonella, E.coli and EWGLI for legionella. Integration of existing EU networks considered by Europe Parliament; WHO EURO to associate
7. Disease occurs naturally in Europe	Increases feasibility	Travel associated or infrequently occurring infections may be suitable e.g. cholera
8. Public health and preventive measures available	Justifies effort	e.g. vaccination or control measures such as improved sanitation and temperature control of foods

Source: WHO-ECEH, 1998b

Table 15. Assessing potential diseases for climate change surveillance: I: High priority infections

Disease	**Continuous/ frequent/ regular surveillance**	**Active surveillance component**	**Clear definition/ diagnostic criteria**	**Aetiology established**	**Significant association with the environment**	**Minimum core data set incl. epidem. factors**	**Sustainable**	**European network ?**	**Sensitive areas**	**Public health approach established**
Campylo-bacter	✓ ☐but mainly just counting	Only in some areas or regions	Typing system developed: more information needed on clinical syndromes	✓ for food; lack of info. on importance of environmental sources. Very low case to case transmission	✓	Incidence, prevalence, travel history, water exposure	✓	No - but possibility of adding to existing network e.g. EnterNet	Common in all countries	Only for outbreaks + some case control studies
Crypto-sporidium	Only in some countries	No - except UK	✓+ typing system to distinguish human/ zoonotic strains	✓ ☐water + zoonotic sources, case to case transmission in children	✓ widely prevalent in water and resistant to chlorination	Incidence, prevalence, travel history, water and agricultural exposure	✓	No - could be established but low number of reports in some countries	Northern Europe + may increase after floods	Only in some countries
Malaria	☐	Info. on travel etc. collated	☐	☐	☐ - water breeding sites also association with temperature and rainfall	Incidence, prevalence, travel history, vector surveillance	☐ - infrequent in Europe; good clinical data	☐ - could be enhanced re: climate	Mediterranean SE Europe, Airport areas	Mainly clinical/ laboratory surveillance: prophylaxis for travellers
Tick borne encephalitis	In some countries	In some countries	☐	☐	✓ - vector patterns changing but also influence of behavioural factors	Incidence, prevalence, morbidity, vector surveillance	✓ - for hospitalised cases	W.H.O.	Endemic areas and areas where vectors expanding	Vaccination, public health advice re: avoiding bites

Source: WHO-ECEH, 1998 b

Table 15 lists four infectious diseases that have been identified by the Working Group as likely to be affected by climate change and includes some characteristics of the surveillance system. These diseases were selected because they are sensitive to climate and because Europe-wide surveillance is already in place. A definite list has still to be developed and further discussed.

The "added value" of Europe-wide surveillance is very important. The observed climate change "signal" may not be detectable at the national level. Therefore, there is a need for regional or continental sized studies of climate change impact assessment. In addition, it is likely that the various impacts of climate change will not be confined to national borders.

6.4.1. Climate and environmental monitoring

There is little research collaboration between the health and the environment sectors in the field of global change. Many global change research and monitoring organizations are interested in health impact assessment and have requested feedback from health researchers. Conversely, many health researchers are unaware of the best sources of climate and environment data (both in situ and remotely sensed data).

Considerable monitoring of those aspects of local environmental conditions that may affect health is already undertaken. Air and water pollution levels are measured regularly by the UNEP Global Environment Monitoring System (GEMS). Monitoring levels of pollutants in air, water, and food, and identifying emission sources, are the most important means of evaluating and regulating such exposure. The GEMS coordinated approach to monitoring of environmental pollution provides a model for the type of multi-centred monitoring that is now essential to the monitoring of climate change impacts.

The WHO/ECEH is developing a Health and Environment Geographic Information System (HEGIS). HEGIS is to be used to identify areas and issues, which are priority for environment and health. Initially, it will focus on demographic and air quality data. There is potential to expand HEGIS including data relevant to climate change and health impacts.

Environment and climate monitoring is also co-ordinated through the Global Observing Systems

Figure 12: The global observing systems

	ATMOSPHERE		LAND	OCEANS
	WWW	**GAW**	**GTOS**	**GOOS**
GCOS		Climate	Climate	Climate
	Weather	Air pollution	Land degradation	Marine services
		Ozone	Pollution	Coastal zone management
			Biodiversity	Ocean ecosystem
			Anthropogenic impacts on natural systems	Living marine resources

Source: McMichael *et al.*, 1996

- Global Climate Observing System (GCOS) is an international effort to provide the scientific and technical framework for documenting the present state of the earth's climate, monitoring its condition, and developing an understanding of its evolution (GCOS, 1995). GCOS co-ordinates the systematic and comprehensive global observation that will lay the foundation for improvements in detecting climate change and predicting climate variability.

- Global Ocean Observing System (GOOS) will provide the essential observations to underpin predictions of El Niño and other climatic events. GOOS co-ordinates efforts to fill the many gaps in the current ocean observing systems and to make it fully comprehensive and fully global. The science and technical design of GOOS will address the following areas: climate; coastal zones; health of the oceans; and living marine resources (UNESCO, 1996).

- GTOS: GTOS will be used to calibrate and validate ecosystem models, to detect and monitor the responses of terrestrial ecosystems to global change, and to observe changes in agro-ecosystems caused by new patterns of land use (GTOS, 1997). GTOS focuses on five issues: changes in land quality; availability of freshwater resources; loss of biodiversity; climate change; and pollution and toxicity. GTOS coordinates interaction between monitoring networks, research programmes and policy makers, particularly for data exchange and application.

The information provided via GCOS, GOOS and GTOS would help nations meet the requirements of global conventions including the UNFCCC. Currently, most monitoring and assessment is targeted at specific issues (e.g. food security, deforestation) and like health data, monitoring is only for a limited duration. However, technological advantages are allowing more investment in and use of decision-support tools. Some policy-makers are also recognizing the value of investing in environmental data and information systems.

At present, health indicators are not included in GTOS. Socio-economic data are being incorporated however and social scientists have now become involved at several levels. Data can be used to validate the models that are being developed to forecast impacts of global change, including health impacts. GTOS are open to new ideas about monitoring and early warning of global change.

6.5 Intersectoral issues

Intersectoral issues are those which involve collaboration between health and other sectors. There is a need to think more broadly than the health sector for effective interventions for many threats to public health. Intersectoral collaboration should be strengthened so that public health considerations are addressed in the implementation of adaptative strategies.

Many of adaptation strategies require collaboration across sectors, for example:
- water quality and water supply;
- agriculture;
- urban development and building design;
- demographic change and the ageing of populations;
- climate monitoring and short-term and long-term forecasting.

The health sector could, in some areas, use information from seasonal climate forecasts or historical climate data in its programmes, enabling more proactive health care planning.

6.6. Research and policy

Collaboration across research disciplines is fundamental to global change research. Barriers to global change research have been identified in Canada and include: lack of national strategic research plans; lack of communication between disciplines; single-discipline funding agencies which do not fund interdisciplinary research; and the lack of public concern which would increase priority with decision-makers (CGCP, 1995).

Research on the health impacts of global environmental change requires a network of scientists within Europe. Research on the health impacts of global environmental change should be conducted within an international framework of scientists. It requires an exploratory and multi-pronged approach with the maximum exchange of information and a cross-fertilisation of ideas and techniques among scientists, agencies and Institutes. There is currently a serious lack of systematic information on climate change and health in the region. There are already several groups in Europe that have begun working on aspects of this topic (e.g. in Sweden, United Kingdom, Netherlands), but there is no forum for communication or dissemination of results.

Priorities for Environment and Health Research for Europe have been identified by consensus between the EC, ESF and WHO EURO. Climate change and stratospheric ozone depletion were identified as a one specific research area of five (EC/ESF/WHO-ECEH, 1998). The recommended research task is:

> "To improve the epidemiological and mechanistic science base and develop predictive methods for the assessment of future health risks of human-induced climate change and increased exposure to UV radiation".

6.6.1. Policy making under conditions of uncertainty

The precautionary principle is most often taken to be that stated in Principle 15 of the 1992 UN Conference on Environment and Development (UNCED):

> "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental damage."

Much has been written on the interpretation and use of the precautionary principle, with debate often around "how much " damage is relevant and what constitutes full scientific certainty. These questions are sharper when uncertainties are substantial.

There are many unavoidable uncertainties attached to the forecasting of potentially serious impacts of global climate change. There is a possibility that irreversible changes in the world’s environment and climate systems may occur. Thus, the "Precautionary Principle" is manifestly relevant to global climate change and stratospheric ozone depletion because of the potentially serious nature of their impacts on health.

7. Conclusions

Human-induced changes in the global climate system and in stratospheric ozone pose a range of health risks. Irrespective of actions that might soon be taken to reduce or halt these environmental changes, human populations will be exposed to some degree of climate change and increased ultraviolet irradiation over the coming decades.

Climate change is likely to have wide-ranging and potentially serious health consequences, including various risks to the health of European populations. Some health impacts will result from direct-acting effects (e.g. heatwave-related deaths, and ultraviolet-induced skin cancer); others will result from disturbances to complex physical and ecological processes (e.g. changes in patterns of infectious disease, in freshwater supplies, and in agricultural yields). Effects on human population health are likely to become evident within the coming decade. It is therefore important to enhance capacity for the detection of the early health impacts of climate change and stratospheric ozone depletion. This can only be achieved by supporting research, monitoring and assessment activities.

Failure to reduce fossil fuel combustion (as the principal means of reducing greenhouse gas emissions) will result directly in a continuing (and increasing) avoidable burden of mortality and disease from exposure to local air pollution.

Climate change is likely to entail serious implications for human health in many countries in Europe. Vulnerable populations need to be identified and adaptive actions must be taken. For example, countries in northern Europe are vulnerable to increased incidence of TBE and in southern Europe are vulnerable to increased local transmission of malaria. Beyond Europe, impacts on food and water supplies and sea level rise could be catastrophic. Climate change may, therefore, exacerbate current problems in peri-European Regions (North Africa, Western Asia, etc.) and indirectly lead to population displacement.

The management of risks to health requires that several steps are taken: awareness that the problem exists; an understanding of what causes the problem; capacity to deal with the cause; a sense of values that the problem is important; and political will (Last, 1995). We now need to redefine as unacceptable many of the personal and industrial practices that contribute to burden of GHGs and thereby pose risks to the health of present and future generations.

8. References

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