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Climate Change and Human Health: Impact and adaptation

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EXECUTIVE SUMMARY

Health is a focus reflecting the combined impacts of climate change on the physical environment, ecosystems, the economic environment and society. Long-term changes in world climate may affect many requisites of good health – sufficient food, safe and adequate drinking water, and secure dwelling. The current large-scale social and environmental changes mean that we must assign a much higher priority to population health in the policy debate on climate change.

Climate change will affect human health and well-being through a variety of mechanisms. Climate change can adversely impact the availability of fresh water supplies, and the efficiency of local sewerage systems. It is also likely to affect food security. Cereal yields are expected to increase at high and mid latitudes but decrease at lower latitudes. Changes in food production are likely to significantly affect health in Africa. In addition, the distribution and seasonal transmission of several vector-borne infectious diseases (such as malaria, dengue and schistosomiasis) may be affected by climate change. Altered distribution of some vector species may be among the early signs of climate change that may affect health. A change in world climate could increase the frequency and severity of extreme weather events. The impacts on health of natural disasters are considerable – the number of people killed, injured or made homeless from such causes is increasing alarmingly. The vulnerability of people living in risk-prone areas is an important contributor to disaster casualties and damage. An increase in heatwaves (and possibly air pollution) will be a problem in urban areas, where excess mortality and morbidity is currently observed during hot weather episodes.

Adaptation is a key response strategy to minimize potential impacts of climate change. A primary objective of adaptation is the reduction, with the least cost, of death, disease, disability and human suffering. The ability to adapt to climate change, and specifically the impacts on health, will depend on many factors including existing infrastructure, resources, technology, information and the level of equity in different countries and regions. Cross-sectoral policies that promote ecologically sustainable development and address the underlying driving forces will be essential in managing health impacts and adaptation measures. Strategies to deal with the impacts of climate change on health need intersectoral, and cross-sectoral adaptation measures and collaboration. The health sector alone, or in limited collaboration with a few sectors, cannot deal with the necessary "primary" adaptation. Sensitive indicators of "climate-environmental" health impacts are needed to monitor possible changes at regional and national levels. Capacity building is an essential step for adaptation and mitigation strategies. This should include education, training and awareness raising, as well as the creation of legal frameworks, institutions and an environment that enables people to take well-informed decisions for the long term benefit of society.

1. INTRODUCTION

Concern for human health is one of the most compelling reasons to study the effects of global climate change. Health is a focus that will reflect the combined impacts of climate change on the physical environment, ecosystems, the economic environment and society. Long-term changes in world climate may affect many of the requisites of good health – sufficient food, safe and adequate drinking water, and secure dwellings. The current large-scale social and environmental changes mean that we must assign a much higher priority to population health in the policy debate on climate change.

1.1. Climate change and human health in the 21st century

The impact of climate change on human health has been given increasing attention since it was first mentioned in the First Assessment Report of the Intergovernmental Panel of Climate Change (IPCC) in 1992. The Second Assessment Report (McMichael et al., 1996) designated a whole chapter to health. At the same time, WHO, WMO and UNEP jointly convened a Task Group to undertake the first comprehensive assessment of the health impacts of climate change (WHO/WMO/UNEP, 1996). In the IPCC's Third Assessment Report (due to be published in 2001), the chapter on health acknowledges the fact that human population health is influenced by the "upstream" environmental and social conditions, which are discussed in other chapters in the report.

Recent developments have placed health at the centre of the debate about sustainable development. Several major international conferences have promoted this new - broader - perspective on health (see Box 1.1).

Box 1.1
Major international conferences on environment and health in the 1990s

1992	United Nations Conference on Environment and Development, Rio de Janeiro.
1992	Tenth Commonwealth Health Ministers Meeting, Nicosia.
1992	UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Helsinki.
1994	International Conference on Population and Development, Cairo.
1994	Second European Conference on Environment and Health, Helsinki.
1994	International Conference on Chemical Safety, Stockholm.
1995	World Summit for Social Development, Copenhagen.
1995	Fourth World Conference on Women, Beijing.
1995	Pan American Conference on Health and the Environment in Sustainable Human Development, Washington DC.
1995	Second Conference on Health, Environment and Development, Beirut..
1996	United Nations Conference on Human Settlements (HABITAT II), Istanbul.
1996	World Food Summit, Rome.
1998	UNECE Convention on Access to Environmental Information and Public Participation in Environmental Decision-making, Århus.
1999	Third European Ministerial Conference on Environment and Health, London.

The protection and improvement of population health must be recognized as a central goal of environmentally sustainable development. Better health, with secure and more equitable access to, and provision of, health services, will require expanded education and training, enhancing further transfer of relevant technologies, an enhanced role of the state as a modern, efficient and transparent institution, more equitable income distribution within countries, international debt alleviation, and an international commitment to sharing the world's common property resources (including the atmosphere).

Rio Declaration, Principle 1. "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature." (UNCED, 1992)

Health is defined by WHO as the state of complete physical, mental and social well-being and not merely the absence of disease and infirmity. Thus, health is widely regarded as a property of individuals rather than of populations. The relative success of modern medicine and the notion that disease avoidance depends principally on personal choice (such as not smoking tobacco) reinforce this view of health as a personal commodity. However, the health of a population is more than the sum of the personal health of its members. Population health encompasses the crucial influence of socially determined conditions such as housing, sanitation, food safety, environmental quality, literacy, and "social capital" (McMichael and Beaglehole, 2000). It is essential that population health is characterized as intrinsically valuable and not principally as an asset or means to economic growth.

1.2 State of the world's health

The profiles of health and disease vary greatly between regions and countries. Noncommunicable diseases (such as cardiovascular diseases, cancer, and depression) predominate in developed countries. In poorer countries, infectious diseases (especially in childhood) remain important, even as noncommunicable diseases increase in urban populations with changes in lifestyle and environmental and occupational exposures. This changing pattern of disease associated with development is called epidemiological transition. Many populations in developing countries are suffering the double burden of disease - increasing incidence of noncommunicable diseases as well as a significant number of infectious diseases. Similarly, the "risk transition" reflects changing patterns of environmental exposures from traditional (e.g. unsafe water and food, inadequate sanitation, and poor housing) to modern (air pollution, chemical exposures, motor vehicle accidents) exposures.

Globally, infectious diseases remain a major cause of human morbidity, and are responsible for about one-third of all deaths (WHO, 1999a). The control, reduction and elimination of infectious diseases are at the centre of many public health programmes. Experiences over the past decades have shown that we are not always winning the battle against infectious diseases. Some major diseases such as malaria and tuberculosis, which were thought to be controlled, have returned.

1.3 Global environmental changes

The phrase "environmental health" in industrialized countries conventionally refers to the adverse effects on human health of exposure to specific physical and chemical agents in the local environment. Notorious "environmental" health events include the nuclear disaster at Chernobyl, the release of the toxic chemical methyl isocyanate at Bhopal, and dioxin at Seveso, pollution at Love Canal and in Minamata Bay, and the great London smog of 1952. The emphasis has thus been on contaminants in air, water, soil and food. Epidemiologists and toxicologists continue to focus on the quantification of these effects — either by studying human populations or experimental animals.

At the beginning of the 21st century, environmental changes on an unprecedented, global scale have begun to impinge upon human health simultaneously, and often interactively (Watson et al., 1998). This spectrum of "global environmental" hazards to health includes:

- global climate change due to the accumulation of greenhouse gases in the lower atmosphere;
- stratospheric ozone depletion (a process that will probably increase for several decades, after which a slow recovery is expected); this will influence skin cancer rates, cataracts, and perhaps, immune system suppression;
- loss of biodiversity - this is occurring at a rapid rate, and entails both the disappearance of useful species and genes and the weakening of various ecosystems thereby reducing the flow of nature's life-supporting "goods and services";
- desertification, depletion of fertile soil, groundwater and natural fisheries; this is undermining

the productivity of food-producing ecosystems, thereby offsetting expected gains from genetically modified organisms, precision farming and aquaculture; and
- various chemical pollutants, familiar as part of industrialization's legacy of local pollution, are now being recognized as persistent and globally pervasive. Some appear to affect neurological, immune and reproductive systems, and can no longer be considered to have specific and limited toxicity.

In addition to the large-scale environmental changes, global trends within human societies have also had significant effects on human health. Table 1.1 illustrates how some of these global trends have been associated with significant changes in infectious disease distribution.
The prime determinant of population health in the medium-to-long term is the life-supporting capacity of the environment (Soskolne and Bertollini, 1999; McMichael and Woodward, 2000). There needs to be a clearer understanding of the fundamental ecological relationship between environmental conditions, climatic conditions and human health. WHO is committed to strengthening healthy environments, social equity and sustainable development. These are the essential ingredients for the improvement and maintenance of population health.

TABLE 1.1.
FACTORS FOR RECENT SIGNIFICANT CHANGES IN THE DISTRIBUTION OF INFECTIOUS DISEASES AND THE EMERGENCE OF NEW DISEASES

Factor	Examples of specific factors	Examples of diseases or causative organisms
Ecological changes, including those from economic development and land use	Agriculture; dams; changes in water ecosystems; deforestation/ reforestation; irrigation; local climate changes	Schistosomiasis (dams); Rift Valley fever (irrigation); Argentine haemorrhagic fever (agriculture); hantavirus pulmonary syndrome (seasonal climate anomalies)
Human demographics and behaviour	Societal events: population growth and migration (movement from rural areas to cities); war or civil conflict; urban decay; sexual behaviour; intravenous drug use; use of high density facilities	Introduction of HIV; spread of dengue; spread of HIV and other sexually transmitted diseases
International travel and commerce	World-wide movement of goods and people; air travel	"Airport" malaria; dissemination of mosquito vectors; rodent-borne hantaviruses; introduction of cholera into South America; dissemination of O139 V. cholerae.
Technology and industry	Globalisation of food supplies; changes in food processing and packaging; organ or tissue transplantation; drugs causing widespread immunosuppression; widespread use of antibiotics.	Haemolytic uraemic syndrome (E. coli contamination of meat), bovine spongiform encephalopathy and human variant CJD; transfusion-associated hepatitis (hepatitis B and C); opportunistic infections in immunosuppressed patients.
Microbial adaptation and change	Microbial evolution, response to selection in environment	Antibiotic-resistant microorganisms, "antigenic drift" in influenza virus, multi-drug resistant tuberculosis
Breakdown in public health measures	Curtailment or reduction in prevention programmes; inadequate sanitation and vector control measures	Resurgence of tuberculosis in the United States; cholera in refugee camps in Africa; resurgence of diphtheria in the former Soviet Union; malaria in S America, eastern Europe, Africa.

Categories are not mutually exclusive; several factors may contribute to the emergence of a disease. *Source: Morse, 1995*

2. The vulnerability of population health to climate change

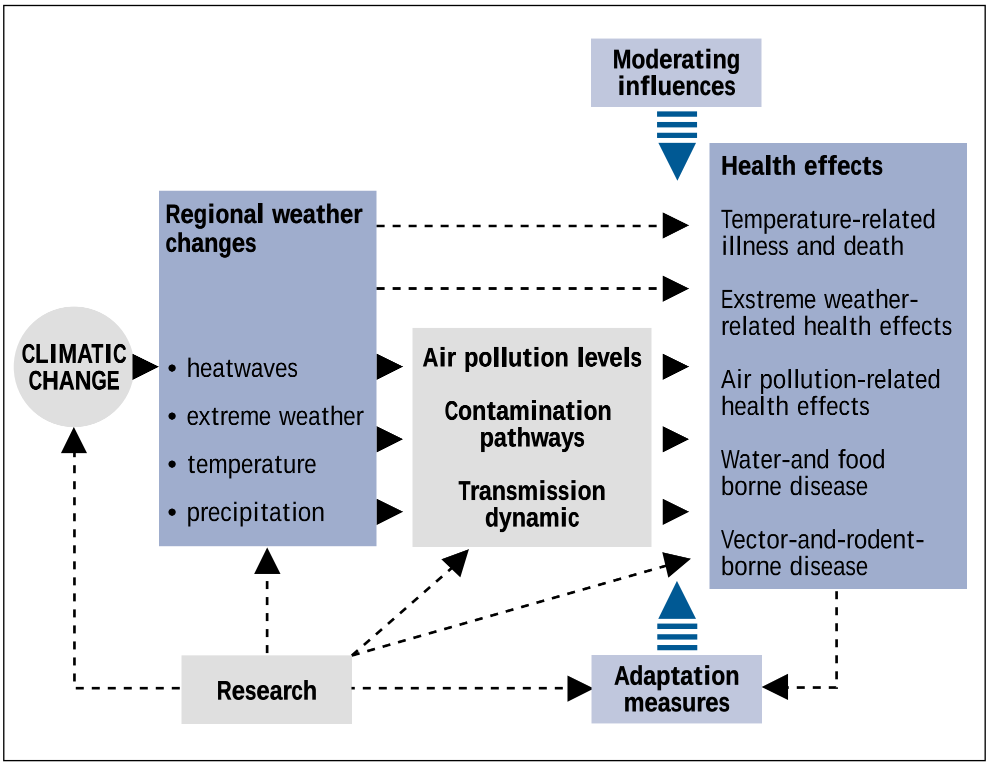
Impact assessment of climate change must consider both the sensitivity and vulnerability of populations to specific health outcomes from climate change (Figure 2.1). Vulnerability is a function both of the exposure to changes in climate and on the ability to adapt to the impacts associated with that exposure.

Little research has been undertaken on population vulnerability in relation to climate change and health. The IPCC *Special Report on Methodological and Technological Issues for Technology Transfer* describes four types of population vulnerability to health impacts: social, economic, technological and demographic (McMichael et al., forthcoming). These categories are directly related to the driving forces of global change (see Box 2.1).

Causes of population vulnerability to ill-health in the face of environmental stress also include the level of dependency (such as reliance on others for information, resources and expertise) and geographical isolation (Woodward et al., 1998; McMichael and Woodward, 2000). The attainment of good public health depends on a responsive social order. Dependency causes vulnerability because support is not always provided when needed. Deprived communities, lacking wealth, social institutions, environmental security and robust health, are likely to be at greatest risk of adverse health effects from climate and other environmental changes. By stretching limited social resources across a broader range of health and other problems, climate change may affect the implementation of public health and nutrition programmes.

Figure 2.1
Pathways by which climate change affects health

Source: Patz et al. 2000



Box 2.1
Driving forces of global environmental changes with significant effects on health in the 21st century

WHO has evaluated trends in health and environment indicators five years on from the Earth Summit (1992) in the report Health and Environment in Sustainable Development (WHO, 1997).

- *Population dynamics.* Population growth, particularly in association with high per capita levels of consumption, can lead to environmental degradation and resource depletion. Significant changes in the age-structures populations have also occurred. Population movement has been increasing rapidly both within and between countries.
- *Urbanization.* Nearly half the world's population lives in urban areas. High population densities, poor quality housing, and local environmental pollution are major problems in most cities, not just in the "slums" of developing countries. Vehicular traffic is also a cause of ill-health through accidents, as well as a major source of local and global air pollution.
- *Poverty, inequalities, and inequities.* Social-economic inequality is continuing to grow both between and within countries (Gwatkin, 2000). In some developing countries more than 20% of children die before they reach the age of five, whereas, in a typical developed country, less than 1% of children do so.
- *Science and technology.* Many technologies have improved health and the environment, although some are polluting, wasteful and can create serious risks to health. Recent technologies that have benefited health include: improved biomass stoves; solar energy (photovoltaic and thermal), especially in remote communities; pesticide impregnated bednets to control malaria.
- *Consumption and production patterns.* Increased consumption associated with development can lead to the depletion of natural resources and environmental degradation. Over-consumption patterns that have direct and indirect health implications include diet, the production and use of chemicals that remain in the environment, as well as the burning of fossil fuels leading to global climate change.
- *Economic development.* Economic development should be considered as a means to reduce poverty and thereby improve health. Macroeconomic policies have major influences on population health in all countries, yet are usually established with little or no consideration of health impacts (WHO, 1992). Structural adjustment policies in some countries have led to cutbacks in health services and increased the burden of disease (e.g. Bijlmakers et al., 1998).

In the past, geography frequently protected populations from the introduction of infectious organisms and agricultural pests. Now, global interconnectedness, the sheer size of the human population and the volume of international travel make such segregation of health risks impossible. For example, the dengue-transmitting mosquito, *Aedes albopictus*, was introduced into the USA from East Asia in shipments of used car-tyres and has now spread throughout much of the American continent (Morse, 1995). The four different serotypes of dengue virus, each of which had a separate distinct geographical distribution, are now distributed throughout much of the world. (A second infection of dengue with a different serotype increases the risk of developing fatal dengue haemorrhagic fever.)

At the individual level, a complex mix of factors determines the degree of vulnerability to ill-health. These factors include: age; gender; disability; social engagement; income; cultural knowledge; legal rights; access to health services; political power; built and natural environment; and physical resources.

2.1 Methods for assessing health impacts

Science classically operates empirically, through observation, interpretation, replication, prediction and, as necessary, modification of the hypothesis. However, having unintentionally initiated a global experiment, we cannot afford to wait decades for sufficient empirical evidence of health consequences; that would be too great a gamble with an uncertain future. Therefore we must assess the risks of future environmental scenarios.

Several important differences need to be considered when health impacts are examined compared to other sectors and foreshadow the difficulties in detecting and quantifying the influences of climate change upon human health:

- most diseases have multiple causes, and socio-economic factors are particularly important as they determine adverse environmental exposures;
- the great diversity in the types of disease: acute and chronic; infectious and non-infectious; physical injury and mental health disorders;
- the many uncertainties regarding the biological and physical processes by which climate or weather affects health;
- the long-term nature of the changes involved; and
- most epidemiological studies have been done on a local basis, and therefore application on a wider scale is difficult.

Direct top-down methods of climate impact assessment are often distinguished from indirect or bottom-up methods (Parry and Carter, 1998). The traditional approach in climate impact assessment answers the question, "if climate changes like this, what will be the effect on specific health outcomes?"

This direct approach is scenario-driven and requires the outputs to be downscaled to the local level. In contrast, bottom-up approaches begin with the questions "what aspects of climate change will affect the system?" and "how much climate change can be tolerated?" These types of studies are directly relevant to Article 2 of the United Nations Framework Convention on Climate Change (see Box 2.2).

Box 2.2
United Nations Framework Convention on Climate Change

ARTICLE 2
The **ultimate objective** of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent **dangerous** anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Where "Adverse effects of climate change" means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on **human health and welfare.**"

ARTICLE 4
All Parties… shall…
(f)....Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, **on public health** and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change;

Various methods have been developed for the quantitative estimation of health impacts of future climatic change (McMichael and Kovats, 2000a, McMichael et al., 2000; Table 2.1). All rely on the study of climate effects on health in the past (e.g. the effects of daily, seasonal or inter-annual climate variability on specific health outcomes) or the present (e.g. climate as a determinant of current disease distribution), or on components of disease transmission cycles described in the laboratory. Global or regional models exist mainly for predicting changes in the distribution and seasonality of the vector-borne diseases malaria and dengue (Martens et al., 1999; Martens, 1998; Patz et al., 1998).

The use of predictive modelling for health impacts of climate change has been limited. Predictive models of physical systems (e.g. coastal flooding) and physiological systems (e.g. crop yield modelling) are well established. However, many aspects of human systems are not readily amenable to modelling. Assessments of health impacts caused by perturbations of complex ecological systems (e.g. changes in the geography of infectious disease vectors) must address the dynamic, non-linear, stochastic behaviour of these systems. The lack of long-term data series on health outcomes means that most climate-health scenarios have only a limited possibility for validation. The projection of scenarios many decades into the future refers to human populations living in unspecifiable circumstances. Most health impact assessments do not yet quantitatively address (autonomous or planned) adaptation. Research into the health impacts of climate change is still at an early stage. Several research needs and knowledge gaps have been identified in the recent United States National Assessment (Table 2.2).

TABLE 2.1.
METHODS OF ASSESSING THE POTENTIAL HEALTH IMPACTS OF CLIMATE CHANGE

Analogue studies	Empirical/statistical	● *Analogue of a warming trend*. e.g. increased malaria in highland region correlated with a local trend in warming. ● *Analogue of extreme events*. e.g. assessment of the mortality impact of a heatwave. ● *Description of basic or recurrent climate/health relationships.* e.g. interannual variation in malaria correlated with minimum seasonal temperature using time series data.
Predictive models	Empirical-statistical models	● *Extrapolation of simple climate/disease relationship using univariate* regression, e.g. daily temperature and mortality. ● *Extrapolation of climate/vector/disease relationship using mapping and statistical methods for use with spatially correlated data*. e.g. mapping tick abundance with climate and other variables.
	Process-based or biological models	● *Models derived from accepted theory can be applied universally.* e.g. forecasting changes in areas suitable for vector-borne disease transmission using a vectorial capacity model.
	Integrated assessment models	● *Multidisciplinary process-based and/or empirical-statistical models linked together horizontally or vertically.* e.g. impact of climate change on food supply and risk of hunger.

Source: McMichael and Kovats, 2000a

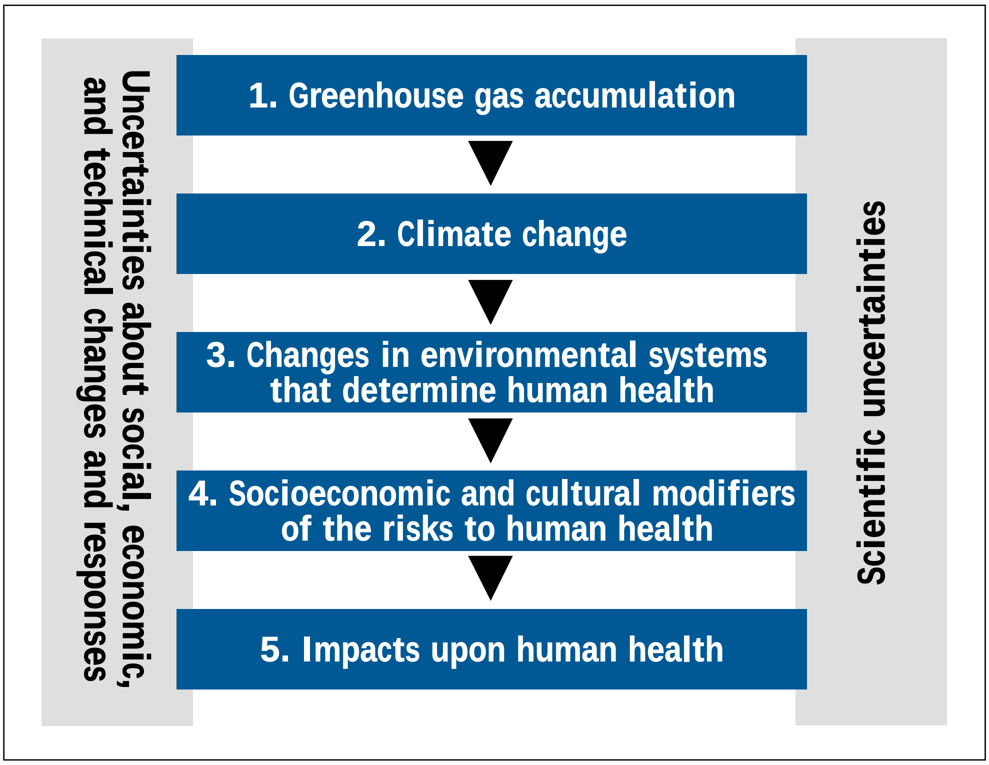


Figure 2.2 Sources of uncertainty in climate health impact and adaptation assessment

Source: McMichael et al., forthcoming

In assessing the potential health impacts of climate change, there are always considerable "upstream" impacts to consider (Figure 2.2), with many uncertainties, including:

- future emissions of greenhouse gases;
- assumptions within the global climate models used to generate climate scenarios;
- other important non-climate factors in the future that will affect health;
- agreement on what is "normal" statistical variation (reflecting the stochastic processes of the real world);
- incomplete knowledge about the structural relationships represented in the impact models; and
- the correct or appropriate values of key parameters in the impact model or the initial conditions.

Participants in the United Nations Framework Convention on Climate Change are obliged to conduct National Communications. These communications address key sectors vulnerable to climate change such as agriculture, forestry and water resources. However, few countries have looked at potential impacts on the health sector (some of these are listed in Box 2.3).

Box 2.3 National Climate Health Impact Assessments

Countries which have conducted reviews of the potential health impacts of climate change.

- Australia (National Health and Medical Research Council, 1991).
- Canada (Canadian Global Change Programme, 1995; Duncan et al., 1998).
- Cuba (Ortiz et al., 1999).
- Czech Republic (Kazmarova and Kveton, 1995; Moldan and Sobisek, 1995)
- Japan (Ando, 1993, Ando et al, 1998);
- The Netherlands (Martens, 1996)
- United Kingdom (Climate Change Impacts Review Group 1996). The UK Department of Health is due to present a report on the health implications of climate change in 2000.
- United States (US Environmental Protection Agency, 1989; Patz et al., 2000).

TABLE 2.2.
SUMMARY OF RESEARCH NEEDS AND KNOWLEDGE GAPS FOR UNITED STATES

Research area	Actions to reduce knowledge gaps
Heat-related morbidity and mortality	● Improvement in the early prediction of heat episodes by determining the key weather parameters associated with poor health outcomes. ● Improvement of urban design to reduce the urban heat island effect. ● Better assessment of personal exposures associated with heat-related illness. ● Predictive modelling of temperature-mortality relationship in different populations. ● Better understanding of the role of air conditioning in reducing impacts. ● Better understanding of role of temperature in excess winter mortality. ● Better understanding of physiological and behavioural acclimatization. ● Improved understanding of preventive measures other than air conditioning.
Weather-related natural disasters	● Improvement of systems to provide early and accessible warning to the populations most likely to be affected. ● Evaluation of the effectiveness of educational materials and early warning systems. ● Better understanding of the longer-term health effects of disasters, such as nutritional deficiencies and mental health effects. ● Standardization of information collected after disasters to more accurately measure morbidity and mortality. ● Monitor the effects of altered land use on vulnerability to extreme weather events.
Air pollution	● Better assessment of exposures due to temperature and air pollutants. ● Health impacts of long-term exposure to high levels of ozone. ● Measuring the health effects of exposure to ozone in people with asthma and other lung diseases. ● Determination of the interaction of ozone with other air pollutants ● Elucidation of the mechanisms responsible for the adverse effects of ozone and other air pollutants in the general population and within susceptible subgroups ● Measures that can moderate the impact of air pollution on health, such as nutrition and other lifestyle characteristics. ● Urban weather modelling of conditions of inversions in urban weather. ● Better understanding of the role of aeroallergens and mould spores in respiratory morbidity.
Water- and food-borne diseases	● Determine the links between land-use and water quality, through better assessment of the watershed level of the transport and fate of microbial pollutants associated with rainfall and snowmelt. ● Formulate methods to improve surveillance and prevention of water-borne disease outbreaks. ● Examine epidemiological studies of water- and food-borne diseases to determine the role of ambient temperature. ● Molecular tracing of water-borne pathogens. ● Understanding of the links between drinking water, recreational exposure, and food-borne disease monitoring. ● Evaluave vulnerability assessments to improve waste and water treatment systems.
Vector- and rodent-borne diseases	● Improvement of rapid diagnostic tests for pathogens. ● Development of vaccines. ● Improvement of active laboratory-based disease surveillance and prevention systems at the state and local level. ● Studies of transmission dynamics (including reservoir host and vector ecology) studies. ● Improvement of surveillance systems for the arthropod vectors and vertebrate hosts involved in the pathogen maintenance/transmission cycles to allow for more accurate predictive capability for epidemic/epizootic transmission. ● More effective and rapid electronic exchange of surveillance data.

Based on Patz et al., 2000

3. KEY IMPACTS RELATED TO CLIMATE CHANGE

Climate change is likely to have wide-ranging and potentially serious health consequences. Some health impacts will result from direct-acting effects (e.g. heatwave-related deaths, weather disasters); others will result from disturbances to complex ecological processes (e.g. changes in patterns of infectious disease, in freshwater supplies, and in food availability). Climate change may also have some benefits to human health, such as reductions in winter deaths in some areas. This report, however, focuses on the adverse impacts of climate change and activities required to reduce such impacts.

3.1 Climate variability and extreme weather events

It is important to distinguish between relations between climate and health and those between weather and health. Climate varies over many time-scales, whereas weather events occur on a typical time-scale of 1-6 days and are associated with many familiar health impacts. These include:

- rainfall events triggering mosquito-borne disease outbreaks (certain mosquito species breed in rain-filled pools);
- rainfall events triggering a flood disaster;
- rainfall events triggering contamination of the water supply with human or animal waste;
- thunderstorms and high humidity leading to short-term increases in hospital admissions for respiratory and cardiovascular diseases;
- heat-waves leading to heat-related illness and death.

Table 3.1 describes the range of mechanisms by which rainfall patterns can affect health. In particular, the El Niño Southern Oscillation has been shown to influence interannual variability in the incidence of malaria, dengue and other epidemic mosquito-borne diseases (Kovats et al., 1999).

Climate change is the long-term alteration in the average weather conditions for a particular location. It will become apparent as a change in annual, seasonal or monthly means of climatological variables. Incremental climate change will be superimposed upon the natural variability of climate in time and space. Therefore, the attribution of a particular weather event (or the health impacts of the event) to anthropogenic climate change is not appropriate. However, long-term changes in the frequency and/or intensity of extremes are a feature of climate change and the impacts of such events need to be addressed. We can infer that climate change will have an effect, for example, when the distribution of a disease is closely linked to winter mean temperatures and when climate factors are shown to affect health. However, where "weather" is seen to have an effect on health, the implication of a change in climate for that particular health outcome is less straightforward. It will depend on how the weather pattern is projected to be affected by climate change. At the local scale, this is often very difficult to determine.

3.2 Natural disasters

Some parts of the world are especially vulnerable to natural disasters for geological or climatological reasons. The principal risk zones for disasters triggered by extreme weather events are tropical Asia and tropical America. In developing countries, populations are becoming more vulnerable to disasters owing to population growth, environmental degradation, and rapid urbanization in disaster-prone areas. World-wide natural disasters kill over 140,000 people per year and affect the lives of more than 100 million (International Federation of Red Cross and Red Crescent Societies, 1998).

The costs of weather-related disasters in the year 1998 alone exceeded the costs of all such disasters during the 1980s. In the Caribbean, the hurricanes George and Mitch killed more than 13,000 people, with Mitch being the deadliest Atlantic storm in 200 years. A cyclone in Orissa, India, in June1998 caused damage comparable to Mitch and an estimated 10,000 deaths. Major floods hit India, Nepal, Bangladesh and much of East Asia, with thousands killed. Two-thirds of Bangladesh was

TABLE 3.1.
THE MANY PATHWAYS BY WHICH RAINFALL CAN EFFECT HEALTH

Event	Type	Description	Example of health impact
Heavy precipitation event	Meteorological	"extreme event"	● increased mosquito abundance or decreased (if breeding sites are washed away)
Flood	Hydrological	river/stream bursts its banks	● changes in mosquito abundance ● contamination of surface water with human or animal waste
Flood	Social	property or crops damaged	● changes in mosquito abundance ● contamination of water with faecal matter and rodent urine (leptospirosis).
Flood	Flood "disaster"	persons killed, injured >10 killed, and/or 200 affected, and/or government calls for external assistance.	● changes in mosquito abundance ● contamination of water with faecal matter and rat urine and increased risk of respiratory and diarrhoeal disease ● deaths (drowning) ● injuries ● health effects associated with population displacement ● loss of food supply ● psychosocial impacts
Drought	Meteorological	evaporation exceeds water absorption, soil moisture decreases. Several indices have been developed based on meteorological variables, e.g. Palmer Drought Severity Index.	● changes in vector abundance if, for example, vector breeds in dried up river beds.
Drought	Agricultural	drier than normal conditions leading to decreased crop production	● depends on socio-economic factors, i.e. whether other sources of food are available as well as the means to acquire them.
Drought	Social	reduction in food supply or income, reduction in water supply and quality	● undernutrition ● increased risk of infection ● increased risk of disease associated with lack of water for hygiene.
Drought	Food shortage/ famine/drought disaster	food shortage leading to deaths >10 killed, and/or 200 affected, and/or government calls for external assistance.	● deaths (starvation, infection) ● underutrition and associated poor health. ● stunting of physical and intellectual development of children. ● health impacts associated with population displacement

Source: Kovats et al., 1999.

flooded for months, leaving millions of people homeless. More than 3,000 people died in China's catastrophic Yangtze River flood, millions were displaced, and the financial cost was estimated to be US$30 billion. Fires ravaged tens of thousands of square kilometres of forest in Brazil, Indonesia and Siberia, with devastating consequences for human health and local economies.

Communities will always have to face natural meteorological hazards, whether floods, droughts or storms. A wide variation in the number and intensity of natural hazards is normal and to be expected. The impact of global climate change will be superimposed on natural climate variability. Changes (increases or decreases) in the frequency of many extremes are likely to be significant, even for small mean changes in climate. The impact of climate change will also influence the upward trend in deaths and number of people affected by natural disasters.

Most disaster victims world-wide (90%) live in developing countries, many living in risk-prone areas, for example on flood plains and unstable hillsides. Unsafe buildings compound the risks. Indeed, the vulnerability of those living in risk-prone areas may be the most important cause of disaster casualties and damage and is compounded by local environmental degradation. Deforestation and the destruction of wetlands reduce the soil's ability to absorb heavy rainfall, making erosion and flooding more likely. It is through poverty and not choice that people in developing countries find themselves living in disaster-prone areas.

3.3 Vector-borne infectious diseases

Many important diseases are transmitted by insect or tick vectors. These organisms are sensitive to temperature, humidity, rainfall patterns and wind, and are therefore potentially sensitive to changes in climate. Many vector-borne diseases that are likely to be affected by climate change have been ranked by WHO as the most important tropical diseases in the world (Table 3.2). The human impact of these diseases is enormous. They affect productivity and cause a vicious spiral of poverty and disability. The distribution and seasonality of many of these diseases may be influenced by climate change. Increases in temperature would tend to accelerate vector life cycles and would also decrease the incubation period of the parasite or virus. Impacts on health would entail the emergence of a disease in new areas as well as the extension of the transmission season in areas where it is present.

Malaria

Malaria is one of the world's most serious and complex public health problems and it has now been identified as the disease most likely to be affected by climate change (WHO/WMO/UNEP, 1996). Countries that are at greatest risk from malaria owing to climate change are those at the fringes of its current distribution, particularly where malaria control programmes have broken down (e.g. in central Asia and Eastern Europe). Environmental conditions are already so favourable for malaria transmission in tropical African countries that climate change is unlikely to affect overall mortality and morbidity rates in hyperendemic lowland regions. The vulnerable areas are those where transmission is currently limited mainly by temperature in highland areas, such as in East Africa (Lindsay and Martens, 1996). However, epidemics are rarely triggered by a single factor such as temperature change - other changes that affect the distribution and seasonal transmission of malaria must be always considered. The re-introduction of malaria into developed countries like the United States of America and those in western Europe is unlikely, provided that public health standards are maintained.

The most recent modelling of climate change effect on malaria indicates that the global population at risk of malaria would increase by an extra 260-320 million people in the 2080s (Martens et al., 1999; Figure 3.1). If there were no climate change, 9 billion people in the 2080s (about 80% of the world’s population) could be classified as at risk of malaria, based on climate factors alone. Currently, about 40% of the world's population is actually at risk of malaria owing to environmental and social factors that limit the disease. The models also project a widespread increase in the seasonal duration of transmission in current and potential new areas. These models need to take into account current vector control measures as well as future developments allowing countries to adapt to changes in disease risk. Global models can be used to identify the areas most vulnerable to increases in malaria due to climate change.

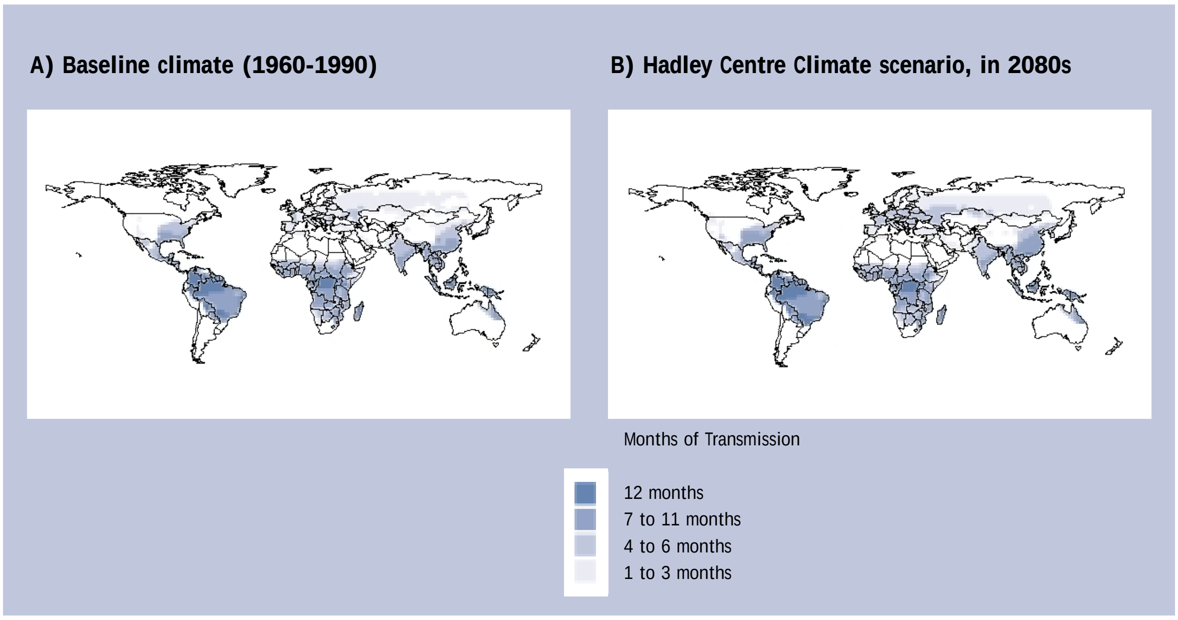


Figure 3.1 The impact of climate change on the *potential* distribution of malaria

Dengue and dengue haemorrhagic fever

Dengue is the most important human arboviral disease transmitted by mosquitoes. More than half the world's population live in areas at risk of infection and up to 100 million cases of dengue occur annually (Rigau-Perez et al., 1998). Dengue is primarily an urban disease in tropical countries, where major demographic changes have taken place. Population movements from rural areas to cities have resulted in the proliferation of settlements with inadequate housing and lack of direct water supply. These conditions provide ideal-breeding sites for vectors (Gubler and Clark, 1995).

Predictive models for dengue transmission project a net increase in the latitudinal and altitudinal range of dengue and increased duration of the transmission season in temperate locations. All studies indicate that the areas of greatest climate-induced change would be at the northern and southern distribution limits of the virus (Jetten and Focks, 1997; Patz et al., 1998). As with malaria, the largest change in potential transmission intensity due to a temperature increase will be in areas where mosquitoes already present, but where development of the virus is limited by temperature.

Schistosomiasis

Schistosomiasis is caused by a flat worm which requires water snails as an intermediate host. World-wide, prevalence has increased mainly owing to the expansion of irrigation systems in hot climates, where snail populations can find human parasite carriers. Data from both field and laboratory studies indicate that climate change may affect the transmission cycle: temperature influences snail reproduction and growth, schistosome mortality, infectivity and development in the snail, and human–water contact (Martens, 1998). In addition, water shortages as a result of climate change could create greater need for irrigation and so an potentially increase in host snail populations.

Table 3.2.
Major tropical vector-borne diseases and the likelihood of change with climate change

Disease	Likelihood of change with climate change	Vector	Present distribution	People at risk (millions)
Malaria	+++	mosquito	tropics/subtropics	2020
Schistosomiasis	++	water snail	tropics/subtropics	600
Leishmaniasis	++	phlebotomine sandfly	Asia/southern Europe/Africa/ Americas	350
American trypanosomiasis (Chagas disease)	+	triatomine bug	Central and South America	100
African trypanosomiasis (sleeping sickness)	+	tsetse fly	tropical Africa	55
Lymphatic filariasis	+	mosquito	tropics/subtropics	1100
Dengue	++	mosquito	All tropical countries	2500-3000
Onchocerciasis (river blindness)	+	blackfly	Africa/Latin America	120
Yellow fever	+	mosquito	tropical South America and Africa	-
Dracunculiasis (Guinea worm)	?	crustacean (copepod)	south Asia/Arabian peninsula/ Central-West Africa	100

+++ = highly likely, ++ = very likely, + = likely, ? = unknown.
Based on: WHO, 1997, WHO/WMO/UNEP, 1996.

3.4 Food security

Population pressures and land degradation undermine current and future attempts to boost food yields. Current assessments of the impact of climate change indicate that some regions are likely to benefit from increased agricultural productivity while others may suffer reductions, according to their location and dependence on the agricultural sector. The IPCC has reviewed the results of many modelling experiments that project future changes in crop yields due to climatic changes. The current assessment is that climate change may increase yields of cereal grains at high and mid-latitudes, but decrease yields at lower latitudes (IPCC, 1996). The world's food system may be able to accommodate such regional variations at the global level, with production levels, prices and the risk of hunger being relatively unaffected by the additional stress of climate change. Integrated assessment models have been used to estimate the additional number of people at risk of hunger due to climate change. One study estimates that Africa will account for the majority of extra people at risk of hunger by the 2080s (Parry et al., 1999).

Malnutrition is a global health problem. Climate change may cause a decrease in food security in some developing countries. FAO estimates that 790 million people in developing countries currently do not have enough to eat. The FAO report on food insecurity (1999) identified population groups, countries and regions which are particularly vulnerable. For example, nearly half the population of countries in central, southern and east Africa are undernourished. Undernutrition is a fundamental cause of stunted physical and intellectual development in children, of low productivity in adults, and of susceptibility to infectious disease in everyone. Climate change is likely to have significant impacts on the health in Africa due to changes in food production.

3.5 Water quality and quantity

Human health depends on an adequate supply of potable water. By reducing fresh water supplies, climate change may affect sanitation systems and lower the efficiency of local sewerage systems, leading to increased concentrations of pathogens in raw water supplies. Changes in rainfall patterns may reduce the water available for drinking and washing. Water scarcity may force people to use poorer quality sources of fresh water, such as rivers, which are often contaminated. All these factors could result in an increased incidence of diarrhoeal diseases.

In developed countries, drinking water receives extensive treatment before it is supplied to the consumer. Such systems need to be maintained to cope with future changes in rainfall patterns, particularly the expected increase in extreme rainfall events. In the USA and UK, outbreaks of cryptosporidiosis have been triggered by heavy rains that overwhelmed the public water supply system (Rose et al., 2000).

The number of people without access to safe water in 1990 was 1.1 billion (WHO/UNICEF, 1996a). Water quality is closely linked to type of water usage and the level of economic development. Large urban populations in developing countries do not have access to safe drinking water sources (standpipes or boreholes) or to sanitation services (sewers, septic tanks or wet latrines).

Flooding may become more intense with climate change and can affect health through the spread of disease (Menne et al., 1999; Noji, 1997). In vulnerable regions, the combination of risks of both food and water insecurity can exacerbate the impact of even minor weather extremes (floods and droughts) for the households affected (Webb and Iskandarani, 1998). The only way to reduce vulnerability is to ensure the infrastructure for the removal of solid waste and wastewater and to supply potable water. No sanitation technology is "safe" when it gets covered by floodwaters, as faecal matter mixes with floodwaters and is spread wherever the floodwaters run.

3.6 Urban quality: heat stress and air pollution

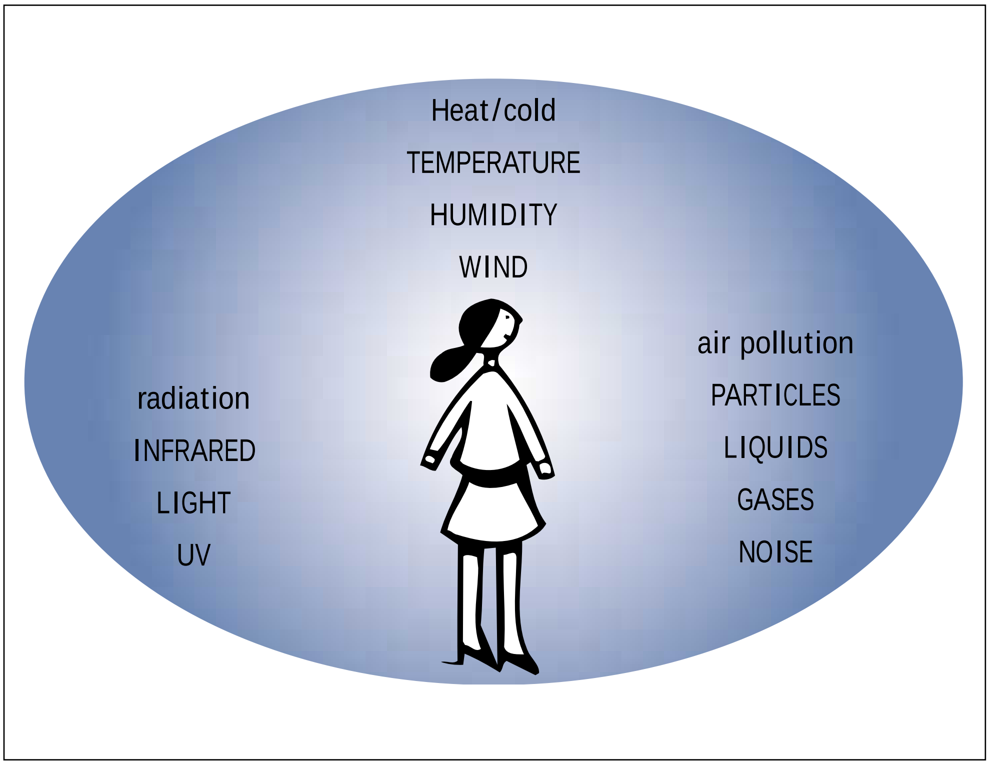
Hot weather is known to cause increased illness and short-term peaks in deaths, primarily in the elderly. A change in world climate that leads to an increase in the frequency and severity of heat waves will worsen this situation. Many urban populations are more vulnerable to heat stress because of the urban heat-island effect. Heatwaves are responsible for a significant proportion of disaster-related mortality in developed countries such as the USA and Australia, where the impact of other weather disasters has been significantly reduced.

People living in hot regions, such as the southern USA or southern China, cope with excessive heat through adaptations in lifestyle and physiological acclimatization. Cultural or social adjustments, including the design of houses for conditions of sustained heat, are important reasons why mortality rates in hotter climates are less sensitive to temperature extremes than in temperate regions. Some physiological acclimatization to heat-stress conditions can occur over a period of several days, but complete acclimatization to an unfamiliar thermal environment may take several years (Frisancho, 1991).

Milder winters resulting from climate change may reduce some of the excess morbidity and mortality associated with cold weather. However, many deaths in winter are caused by respiratory infections and are not directly related to temperature. It is not clear how rates of winter mortality would be affected by climate change. In countries with a high level of excess winter mortality, e.g. the United Kingdom, the beneficial impact may outweigh detrimental impacts. However, the severe weakening or collapse of the Gulf Stream in the North Atlantic would cause cooling over North-West Europe. Although this scenario is unlikely, it would have important implications for cold-related diseases.

The air around us contains particles and gases which may affect our health, such as pollen, fungal spores, and pollutants from emissions arising from the combustion of fossil fuels (Figure 3.3). These air pollutants have many sources: natural (e.g. vegetation fires and volcanoes), agricultural (e.g. methane and pesticides), commercial activities (e.g. dry cleaning operations and vehicle repair shops), industrial (e.g. electric power plants and manufacturing facilities), transportation (vehicle emissions),

Figure 3.3 The atmospheric environment



and residential (home gas, oil burners and wood stoves). Weather conditions affect air pollution by transport and/or formation of pollutant or its precursor. Climate change may affect exposures to air pollutants via several mechanisms (Patz et al, 2000):

- altering weather patterns (e.g. winds and frequency of temperature inversions) and thereby decreasing or increasing local and regional pollution concentrations (e.g. Penner et al., 1989; Robinson, 1989);
- through anthropogenic emissions, including adaptive responses such as increased fuel combustion or mitigation policies for emission reduction;
- affecting natural sources of air pollutant emissions (USEPA, 1998); and
- the distribution and types of airborne allergens (e.g. pollen and mould spores) (Emberlin, 1994).

The main urban air pollutants are: ozone, nitrogen oxides, carbon monoxide, sulphur dioxide, particulate matter, and volatile organic compounds. All cause damage to human health. Ground level ozone can exacerbate respiratory diseases by damaging lung tissue, reducing lung function, and sensitizing the lung to other irritants. Particulate matter can aggravate existing respiratory and cardiovascular diseases, alter the body’s defence mechanisms against foreign material, damage lung tissue, and may cause cancer and premature death. Health effects of exposure to carbon monoxide, sulphur dioxide, and nitrogen dioxide include visual impairment, reduced work capacities, aggravation of existing cardiovascular disease, effects on breathing, respiratory illness, and lung irritation. The most direct effect of climate change may be the impact of increased temperature on concentrations of ground-level ozone, but the magnitude of change is uncertain. For other pollutants, the effects of climate change are less well studied.

3.7 Social disruption

In 1990, the IPCC noted that "the greatest effect of climate change may be on human migration as millions of people will be displaced due to shoreline erosion, coastal flooding and agricultural disruption." Refugees represent vulnerable populations with significant health problems. Large-scale migration is likely in response to flooding, drought and other natural disasters associated with climate change. Both the local ecological disturbance caused by the extreme event and the circumstances of population displacement and resettlement would affect the risk of infectious disease outbreaks. An increase in the magnitude and frequency of extreme events would also disrupt political stability. Displacement due to longer-term cumulative environmental deterioration (e.g. land degradation and water scarcity) is also associated with many health impacts.

4. Likely effects on human health within the next decades

Major weather disasters in recent years have affected the health of thousands of people. Although it is not possible to attribute particular extreme weather events to climate change, climatologists have stated that these types of meteorological events are more likely owing to climate change (IPCC, 1996).

There is good evidence that observed regional warming has affected natural ecosystems. Plant growth has increased in higher latitudes and plants in highland areas have spread to higher altitudes. Changes in the distribution and behaviour of animal species in response to changes in climate have also been confirmed from records collected over decades (Parmesan, 1996; Crick and Sparks, 1999).

It is likely that the first detectable changes of significance to health will be alterations in the geographical range (particularly altitude) of certain vector species. Changes in the northern limit of the disease-transmitting European tick, *Ixodes ricinus*, in Sweden over the last two decades have recently been attributed to climate warming (Lindgren et al., 2000).

Effects on human health are likely to become evident within the coming decades (Kovats et al., 2000). The time frame for the emergence of health impacts of climate change will depend on several factors:

- the "incubation" period (i.e. delay between an environmental event and the onset of ill-health), which ranges from almost zero (e.g. from storm-induced injury), to weeks or months (e.g. from vector-borne infections); to years and to decades (e.g. from UV-related malignancies); and
- factors influencing "detectability" – if a change occurs - the extent and quality of information and variability in the background or pre-existing level of disease must be considered. The first moment of detecting the health impacts of climate change will depend on three primary determinants:
  - the sensitivity of response (i.e. how steep the rate of change is) for a given temperature change;
  - the sensitivity of the response to non-climate factors (confounders);
  - possibility of determining a threshold level/value.

Debates have focused on recent increases in malaria in the highlands of East Africa (Lindsay and Martens, 1996; Mouchet et al., 1998). It is unlikely that the argument can be resolved owing to the lack of long-term information on the incidence and distribution of malaria in these regions (Cox et al., 1999). Other factors that have significantly increased malaria distribution in recent years include: population movement, deforestation, drug resistance and changes in vector control programmes.

Detecting the influence on health from long-term climate change in health outcome data is difficult owing to the large interannual variability in most health outcomes. Furthermore, the past 10-20 years have seen changes in many important factors not related to climate, affecting health outcomes such as: improved reporting, improved detection, and changes in health care, treatment, and exposures not related to climate (Campbell-Lendrum et al., 2000; Menne et al., 2000).

5. Adaptation to climate change and climate variability

The primary objective of adaptation is to reduce disease burdens, injuries, disabilities, suffering and deaths. Many impacts of climate change - including health impacts - can be reduced or avoided by various adaptations (Smit, 1993; MacIver and Klein, 1999).

The key determinants of health – as well as the solutions – lie primarily outside the direct control of the health sector. They are rooted in areas such as sanitation and water supply, education, agriculture, trade, tourism, transport, development and housing. Unless these aspects are considered, it will be difficult to make improvements in population health. Primary and secondary adaptive measures, intersectoral and cross-sectoral adaptation strategies are needed to reduce the potential health impacts arisen from climate change. However, it is very difficult to disentangle most of these measures from the general strategies of public health.

5.1 Types of adaptation

Criteria that apply to all sectors for distinguishing between adaptation strategies have been developed. Depending on the timing, goal and motive of its implementation, adaptation can be either *reactive* or *anticipatory*. Reactive adaptation occurs after the initial impacts of climate change have appeared, while *anticipatory* (or proactive) adaptation takes place before impacts are apparent. A second distinction can be based on whether the adaptation is motivated by private or public interests. Private decision-makers include both individual households and commercial companies, while public interests are served by governments at all levels (Klein, 2000, Table 5.1).

A distinction is often made between *planned* and *autonomous* adaptation (Carter et al., 1994).

Planned adaptation is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to or maintain a desired state. *Autonomous* adaptation involves the changes human systems will undergo in response to changing conditions, irrespective of any policy, plan or decision. Human beings are likely to undergo certain biological or physiological adaptation in response to climate change - particularly acclimatization to warmer climate regimes. Autonomous adaptation responses will also include behavioural and other activities triggered by market or welfare changes. Autonomous adaptation would therefore be in the individual's rational self-interest, while the focus of planned adaptation would be centred on collective needs. Thus, autonomous and planned adaptation largely correspond with private and public adaptation (Table 5.1.).

TABLE 5.1.
TYPES OF ADAPTATION TO CLIMATE CHANGE

	Anticipatory/proactive	Reactive
Private	• *Purchase of insurance* • *Construction of "disaster" resistant houses*	• *Changes in insurance premiums*
Private	• National disaster insurance fund • Urban planning • New building codes, design standards • Incentives for relocation • Immunization campaigns	• Monitoring and surveillance • Compensatory payments and subsidies • Enforcement of building codes, design standards

Adapted from Klein, 2000

Article 3.3 of the United Nations Framework Convention on Climate Change suggests that anticipatory adaptation deserves particular attention from the international climate-change community. Five generic objectives of anticipatory adaptation, which is aimed at reducing a system's vulnerability by either minimizing risk or maximizing adaptive capacity, can be identified (Klein and Tol, 1997):

- *increasing the robustness of infrastructural designs and long-term investments*—for example, by extending the range of temperature or precipitation, which a system can withstand without failure, and changing the tolerance of loss or failure (e.g. by increasing economic reserves or by insurance);
- *increasing the flexibility of vulnerable managed systems*—for example, by allowing mid-term adjustments (including change of activities or location) and reducing economic lifetimes (including increasing depreciation);
- *enhancing the adaptability of vulnerable natural systems*—for example, by reducing other (non-climatic) stresses and removing barriers to migration (animal or human?) (including establishing eco-corridors);
- *reversing the trends that increase vulnerability ("maladaptation")*—for example, by introducing setbacks for development in vulnerable areas such as floodplains and coastal zones; and
- *improving societal awareness and preparedness*—for example, by informing the public of the risks and possible consequences of climate change and setting up early-warning systems.

Downing et al. (2000) have proposed two types of anticipatory adaptation: *no-regrets* and *low-regret*. *No-regret* anticipatory actions are those in advance of impacts, which benefit social development goals: for example, disaster preparedness, famine early warning systems, improved health-care systems,

TABLE 5.2.
EXAMPLES OF PRIMARY AND SECONDARY ADAPTIVE MEASURES TO REDUCE HEALTH IMPACTS

Impact	Primary adaptive measures	Secondary adaptive measures
Heat stress	● Heatwave warning systems ● Urban planning	● Health personnel educated to detect and treat heat stress
Extreme weather events	● Disaster preparedness and mitigation ● Early warning systems ● Disaster protection measures, such as "room for the river"	● Disaster response
Infectious diseases	● Integrated environmental management	● Disease surveillance and monitoring ● Control of vector-, food- and water- borne diseases
Food security	● International mechanisms of agriculture, trade and finance ● Seasonal climate forecasting ● Famine early warning systems ● National and local agriculture measures, such as tailored land use planning, avoidance of monocultures, upgraded food storage and distribution systems, conservation of soil moisture and nutrients	● Monitoring and surveillance ● Implementation of nutrition action plans
Water	● Pollution reduction and pollution control policies ● Demand management and water allocation policies ● Waste water treatment ● Economic and regulatory measures to increase irrigation efficiency ● Capacity building	● Monitoring and surveillance ● Capacity building

Source: Menne, 2000a

building design to reduce heat stress. *Low-regret* anticipatory actions are those where costs are low in comparison to benefits: for example, the marginal increase in the height of a bridge for possible sea level rise.

Adaptive actions to reduce health impacts can be thought of in terms of the classical categorization of preventive measures in public health (McMichael and Kovats, 2000b; Figure 5.1; Table 5.2.):

- *primary adaptive measures:* actions taken to prevent the onset of disease arising from environmental disturbances, in an otherwise unaffected population (e.g. supply of bed nets to all members of a population at risk of exposure to malaria, early warning systems, integrated environmental management) - primary prevention is analogous to anticipatory adaptation;
- *secondary adaptive measures:* preventive actions taken in response to early evidence of health impacts (e.g. strengthening disease surveillance and responding adequately to disease outbreaks) - secondary prevention is analogous to reactive adaptation; and
- *tertiary adaptive measures:* health-care actions taken to lessen the morbidity or mortality caused by the disease (e.g. improved diagnosis and treatment of malaria)

Primary adaptive measures can be addressed at many levels – including the mitigation of climate change itself (e.g. reduction of greenhouse gas emission). In general, secondary and tertiary measures are less effective than primary prevention, although they are often practically and politically easier to implement. There are ethical and social reasons to prefer primary preventive action wherever it is feasible. In the long term, secondary and tertiary prevention measures usually are more expensive than primary prevention (McMichael and Kovats, 2000b). However, the cost effectiveness of preventive strategies depends on the structure of the programme and the population at risk (Haddix et al., 1996).

Criteria for evaluation of adaptation strategies are outlined in Table 5.3. Different parameters are taken into consideration, such as application at the global, regional and local levels, number of people that benefit from the strategies, feasibility and costs. The reduction in human mortality and morbidity should also be considered.

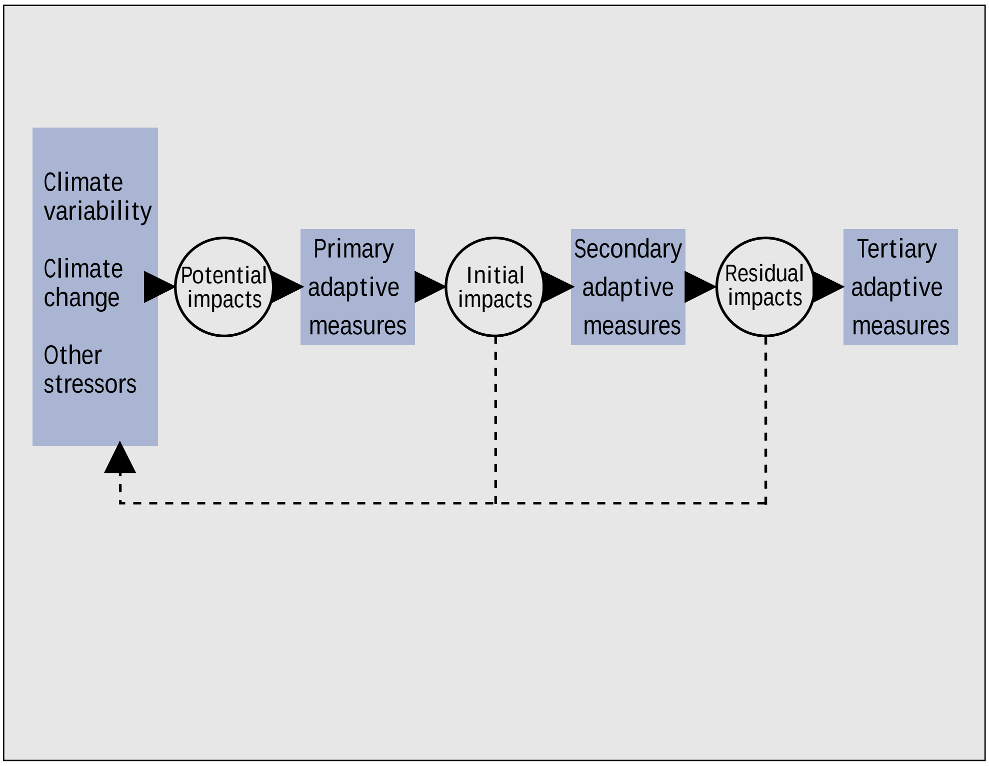


Figure 5.1 Framework for impact and adaptation assessment

5.2 Disaster preparedness and mitigation

The spatial and temporal scale of natural hazards varies widely from short-lived, violent, phenomena of limited extent (e.g. tornadoes and severe thunderstorms) to larger systems (e.g. tropical cyclones and extra-tropical cyclones) which can subject whole countries or regions to strong winds, flood-producing rains, storm surges, and coastal flooding for several days. El Niño-related droughts may affect huge sub-continental areas for months to years, causing food shortages, mass migration, desertification, loss of animal populations and an increased risk of forest fires (Zillmann, 1998).

Classically there are four phases of disaster reduction (World Conference on Natural Disaster Reduction, 1994):

- mitigation: long term activities undertaken prior to impact aimed at reducing the risk or occurrence and/or effect of a disaster;

- preparedness: pre-disaster activities intended to increase the effectiveness of emergency response during a disaster;
- response: activities undertaken immediately before and during an event, to protect lives and properties; and
- recovery: post-disaster activities undertaken in order to return affected communities to a more normal condition.

Mitigation and preparedness activities depend on the adopted regional and/or national strategies. Coordination between the different agencies is crucial during disasters. Preparedness activities include rapid assessment of health needs, strengthening of early warning systems, capacity building at national and local levels and information management systems. Box 5.1 outlines different assessments whose execution is important in between or before floods events (WHO, 1995). Box 5.2 outlines different steps for disaster reduction, before, during and after Hurricane Mitch (Tieren, 1999).

Table 5.3.
Adaptation options to reduce the potential health impacts of climate change

Adaptation option	Level	No of people that benefit	Feasibility	Barriers	Cost
Interagency co-operation	G, R, N	+++	++	++	+
Improvements to public health infrastructure	N,L	+++	+	+	++
Early warning and epidemic forecasting	L	++	++	+	+
Support for infectious disease control	N,L	++	+++	+	+
Monitoring and surveillance	N,L	++	+++	+	+
Integrated environmental management	L	+	++	+	++
Urban design (including transport systems)	L	+	+	++	++
Housing, sanitation, water quality	L	+	+	+	+
Specific technologies (e.g. air conditioning)	L	+	+++	+	+
Public education	L	+++	+++	+	+

G = Global, R= Regional, N = National, L = Local, +++ = large effect, ++ = medium effect, + = small effect.
Source: McMichael et al., forthcoming in IPCC Special Report on Technology Transfer.

Box 5.1
Pre-flood assessments

WHO has prepared guidelines to reduce the impact of flooding on human health (WHO, 1995).

- Mapping of potential risks, the estimated frequency, location of chemical and nuclear plants and other hazardous sources, location of dwellings, location of public buildings and transport systems at risk.
- Vulnerability analysis, taking into account population density, vulnerable structures, economic aspects. The traditional methods for coping with floods should be carefully evaluated, and included into the preparation of contingency planning.
- Inventory of existing resources, including infrastructure, personnel communication, transport, health services, medical stocks, in order to facilitate the rapid mobilization of all reliable resources. The inventory should be frequently updated, including resources available from NGO's, the private sector and the army.
- Preventive measures in the health sector include preparedness in medical supply management.
- Establishment of a regional or national co-ordination mechanism including the health sector

Box 5.2
Emergency relief following hurricane Mitch
(adapted from Tieren, 1999)

The Pre-existing State of Preparedness: Disaster co-ordination and response mechanisms were already in place when Hurricane Mitch struck Central America. Emergency committees were rapidly created within each sector.

Immediate Response and Rehabilitation. The magnitude of the Hurricane rapidly exhausted the national capacity for response. Rapid situation assessment missions were immediately deployed by the Government and its partners, in particular WHO. A few days after impact, the health sector through the World Health Organization and its Regional Office for the Americas as well as the food aid sector through the World Food Programme released an initial appeal for assistance. Meanwhile, the United Nations Disaster Assessment and Co-ordination (UNDAC) undertook a broader based impact assessment. On 4 December 1998, a combined United Nations Inter-Agency Transitional Appeal for Relief and Immediate Rehabilitation was launched for Honduras, Nicaragua, El Salvador, Guatemala, and Belize. This initiative would address the needs during the 6 month period before the finalization of country-specific reconstruction projects.

Post-Disaster Reconstruction. The health sector aims to return the level of health and use of health services to the level before the disaster. This requires investment in country-scale public health interventions, including immunization campaigns, water quality control, vector-control and sanitation, nutrition and food safety as well as primary health care services and hospital rehabilitation. Similar post-disaster reconstruction efforts include education, agriculture and transport, infrastructure. In parallel to the assistance and rehabilitation activities, the national government and the international community insisted on the importance of strategies for long-term post-disaster reconstruction. On 6 November 1998, the UN Secretary General appealed to the leading world financial institutions, the World Bank, the International Bank of Development, and the International Monetary Fund to allow the countries of Central-America to absorb the economic burden of post-disaster reconstruction. As a result, co-operation agreements, both bilateral and multilateral, were signed between Government representatives and their financial counterparts, "soft" loans were allocated, credit liberated, external debts reduced or even in some instances suppressed. Hurricane Mitch illustrates clearly that the concepts of emergency preparedness, emergency response and rehabilitation, post-disaster reconstruction and disaster mitigation are inter-related. These activities constitute the core elements of a well-integrated disaster management practice whose objective is to maintain development growth despite the inevitable occurrence of natural disasters. For example, in the health sector, continued assistance through a package of communicable diseases control measures and primary health care rehabilitation has kept the health situation in the affected countries under control. Although sporadic cases of cholera, malaria, dengue were and continues to be regularly reported from the affected area, no widespread epidemic occurred.

5.3 Weather forecasting, seasonal forecasting and early warning systems

Weather and climate forecasts and early warnings may be used to provide information, which enables and persuades people and organisations to protect themselves and their property, and thereby reduces the deaths, injury and damage caused by the hazard.

Weather forecasting

Through the contribution of modern meteorological and hydrological sciences and technology such as meteorological satellites, weather radar, and numerical weather prediction models, it is possible to provide communities threatened by potential major disasters with information to allow them to take preventive action in time. Early warning can avert enormous loss of lives and social turmoil. Accurate weather forecasts can now be provided up to 10 days in advance. Five-day weather forecasts, routine in many countries, have saved millions of lives through warnings of hurricanes, floods and other severe weather events (Noji, 1997). Although one cannot predict the exact location or intensity of severe storms before they develop, it is possible to detect and locate atmospheric conditions likely to produce such storms up to 6-12 hours ahead with a geographical accuracy of about 200 km (Zillmann, 1998). In the case of tornadoes, the warning time has doubled from about 8 to 9 minutes in 1990 to more than 17 minutes by the end of the past decade.

Scientific knowledge alone, however, will not solve the problem. Meteorological and hydrological agencies must become involved with other governmental organizations, local and national officials, emergency managers, local decision makers, the media, voluntary organizations, and weather-sensitive businesses (known collectively as the hazards community) to create effective preparedness plans, warning systems, mitigation strategies and public education programmes. This point can be amply demonstrated in the case of tropical cyclones. Deaths have been dramatically reduced owing to meteorological forecasts, systems to disseminate forecasts, emergency preparedness and the building of storm shelters. Links between health-related early warning systems already in existence, such as the Global Information and Early Warning System (GIEWS), ProMED and the WHO outbreak investigation network, will need to be strengthened and new ones created.

Seasonal forecasting

Advances in seasonal forecasting are generating new opportunities to mitigate the impacts of climate variability on health. Seasonal regional climate forecasts have proved useful in guiding farmers in Brazil, Peru, Zimbabwe, and other countries in the planting of drought-resistant crops and the management of fisheries during El Niño years. Seasonal forecasts have been included into many local and regional famine and drought early warning systems (Glantz, 1994). However, dangers of poor forecasts can undermine confidence in the whole forecasting system, as happened during the incorrect forecast of a severe drought in South Africa during the El Niño of 1997/98 (Pfaff et al., 1999). Decision-makers should be included in the process of assessment to better understand the uncertainties of these forecasts.

Associations have been described between El Niño and malaria epidemics in Asia and South America (Bouma and Dye, 1997; Bouma and van der Kaay, 1996; Kovats et al., 1999). The use of climate forecasts for epidemic prediction needs to be linked with early warning systems of known epidemic risk factors (e.g. heavy rainfall). Initiatives to develop these new approaches for the surveillance and control of epidemic malaria in East and Southern Africa and India should be supported (NOAA, 1999).

Hot weather watch/warning systems

A good example of collaboration between meteorological and health services is the development of hot weather watch/warning systems. Such systems are based on the identification of air masses associated with increased mortality (Kalkstein et al., 1996). The early warning systems can predict specific air masses up to two days in advance. Once an air mass is classified as oppressive with the likelihood of high mortality, a "health warning" is issued to the public health authorities, which prepare a public health response. These systems have been used in Philadelphia and other cities in the USA and are now tested or developed in Rome and Shanghai. In the USA, public health actions in response to the warning include: encouraging the elderly to stay in "cool" environments, such as public buildings; alerting general practitioners and hospitals; preparing community-based volunteers to assist disabled and the elderly. However, these preventive measures might not be applicable to other sociocultural contexts. Sentinel surveillance in emergency departments can also be used to monitor increases in heat-related cases.

5.4 Monitoring and Surveillance

The most elementary form of adaptation is to launch or improve health monitoring and surveillance systems (WHO/WMO/UNEP, 1996; WHO/MRC/UNEP, 1998). Table 5.4 summarizes the mechanisms for a comprehensive monitoring scheme for the types of potential health impact of climate change (Haines and McMichael, 1997). A first step would be to select climate-environmental health indicators to be monitored at a regional or national scale. There are, however, difficulties as different agencies, ministries, institutions and international organizations monitor most of the data. For example, in the health sector, only the basic measures of public health status (e.g. mortality) can be measured simply and uniformly around the world as births and deaths are reported in most countries.

The collection of data on disease (morbidity) is often difficult. Since 1992, the alarm over emerging and re-emerging diseases has resulted in national and international initiatives to restore and improve both surveillance and control of communicable diseases (WHO, 1999b). The World Health Assembly in 1995, urged all Member States to strengthen surveillance for infectious diseases in order to detect promptly re-emerging diseases and identify new infectious diseases. The success of the implementation of this resolution depends on the ability of researchers to obtain the necessary information and the willingness to share it nationally and internationally. However, disease (morbidity) monitoring and surveillance varies widely depending on the locality and the disease. Many developed countries have poorly developed surveillance systems and lack the resources and expertise for collecting appropriate data to monitor the impacts of climate change effectively. Data sharing and capacity strengthening for local data collection and the development of integrated early warning systems are important. A strong public health infrastructure – international, national and local – along with active local community involvement is necessary to achieve an effective response to information provided by the surveillance of infectious diseases. WHO monitoring activities are based mainly on networks of networks. The geographical and population data gaps, as well as network expertise deficiencies must be rectified. They need to represent both human and animal infections and provide information on antimicrobial resistance and the environment including water, insect vectors and animal reservoirs.

WHO has developed a world-wide network of laboratories and reporting sites that collects information on reported (and rumoured) outbreaks nationally and world-wide — the Outbreak Verification Network. Once confirmed, information is made available immediately on the internet. WHO forms partnerships to investigate and contain those outbreaks which could spread internationally and require concerted action. ProMED, a network for the exchange of information on outbreaks of new and resurgent infectious diseases, is another world-wide example of successful communication (Morse, 1995). Early warning systems and prompt intervention to contain an outbreak can be highly cost-effective as well as saving lives. In Peru, an epidemic of cholera in 1991 cost an estimated $770 million in lost trade and tourism - almost one-fifth of normal export earnings (WHO, 1999b).

WHO collaborates with other UN agencies on several monitoring programmes. For example, the Global Environmental Monitoring System (GEMS) provides monitoring and assessment of air and water quality. International monitoring programmes could be extended to include exposures to the direct and indirect health hazards associated with climate change and sea level rise (McMichael et al., 1996; WHO/MRC/UNEP, 1998). Furthermore, WHO could better liase with the global observing

TABLE 5.4.
SUMMARY OF METHODS NEEDED TO MONITOR THE POTENTIAL IMPACTS OF CLIMATE CHANGE AND CLIMATE VARIABILITY ON HUMAN HEALTH

What	Where	How
Heat stress	Urban centres in developed and developing countries	Daily mortality and morbidity data
Changes in seasonal patterns of disease (e.g. asthma, allergies)	"Sentinel" populations at different levels	Primary health care morbidity data, hospital admissions, emergency room attendance.
Vector-borne diseases	Margins of distribution (latitude and altitude). Areas with seasonal and sporadic incidence.	Primary health care data; local field surveys, communicable disease surveillance centres; remote sensing data. Surveillance of infectious disease must be active and laboratory-based.
Marine ecosystems	Coastal populations, coastal zones.	Sampling of phytoplankton for biotoxins, pathogens. Remote sensing of algal blooms. Epidemiology of cholera, other Vibrios and shellfish poisoning.
Natural disasters	All regions	Mortality and morbidity data.
Effects on health of sea level rise	Low-lying regions	Local population surveillance.
Freshwater supply	Critical regions especially in the interior of continents	Run-off measures; irrigation patterns; pollutant concentrations.
Food supply	Critical regions	Remote sensing; measures of crop yield; food access and nutrition from local surveys. Agricultural pest and disease surveillance.
Emerging diseases	Areas of population movement or ecological change	Identification of "new" syndromes or disease outbreaks; population-based time series; laboratory characterizsation.

Source: Haines and McMichael, 1997

systems by providing health data; meanwhile it would be informed by the global observing systems of significant ecosystem, water, permafrost, and climatic changes (Global Climate Observing System/Global Terrestrial Observing System, 2000).

Effective surveillance and monitoring demands global cooperation and exchange of information, as well as the modernizing of monitoring and surveillance systems. Such initiatives should build on current successes and integrate different monitoring networks.

5.5. Control of vector-borne and water-borne diseases

Populations can be protected from vector-borne diseases by cost-effective interventions, in addition to the surveillance strategies described above. For example, immunization campaigns can be extremely cost-effective once a suitable vaccine has been developed. The coverage of existing vaccination programmes aimed at eliminating diseases should be expanded. Unfortunately, no vaccines yet exist for some of the diseases most sensitive to climate change, e.g. malaria, dengue and schistosomiasis, or for many newly emerging infections. Examples of currently existing control strategies for malaria and dengue are outlined below. These strategies should be strengthened in all vulnerable regions, whether or not climate change is likely to affect transmission.

Malaria

Global malaria control strategies include early diagnosis and prompt treatment, selective and sustainable preventive measures, including vector control, early detection, and containment or prevention of epidemics. Local capacity building for basic and applied research is essential to allow the regular assessment of the malaria situation, particularly the ecological, social and economic determinants of the disease. Advances in the mapping of malaria using satellite data, validated with surveillance information, will help to target control efforts (Craig et al., 1999; Snow et al., 1996). Table 5.5 highlights malaria to indicate some types of adaptive strategies, and the levels at which they operate. For example, specific products for vector control, malaria vaccines, and drugs are developed around the world under the guidelines of WHO. However, the local use of the products depends on

TABLE 5.5.
TYPES OF ADAPTIVE STRATEGIES USING MALARIA AS AN EXAMPLE

Level	Vector Control	Vaccine Development	Access to anti-malarial drugs	Preventive measures such as bednets, housing design	Epidemic forecasting	Environmental management
International	++	++	+++	+	-	-
Regional or Federal	++	-	++	+	-	-
National or State	+++	-	+++	+	+++	+
Local or community	++	-	+	++	++	+++
Individual	+++	-	+	+++	+	++

+++ = very important strategy, ++ = important strategy, + = not so important strategy, - = no strategy available.
Source: GITHEKO, personal communication

national policies and demand by users. As the risk of malaria due to climate change will be mainly in temperate zones and highlands, health systems there will need to be fully prepared to properly diagnose, treat and control the disease.

Dengue

There is no specific treatment for dengue. Moreover, vaccine development is difficult since any of four different dengue serotypes may cause the disease, and because protection against only one or two of these serotypes might actually increase the risk of more serious disease. At present, the only method of controlling or preventing dengue and dengue haemorrhagic fever is to combat the vector mosquito which, in Asia and America, breeds primarily in man-made containers such as bottles and used tyres. Elements of a global strategy to control dengue include:

- surveillance of vector densities and disease transmission;
- developing selective and sustainable vector control, including preparedness for emergency control;
- strengthening local capacity for assessment of the social, cultural, economic and environmental factors that lead to increased vector densities and increased transmission of disease;
- early diagnosis and prompt treatment of dengue haemorrhagic fever
- research in vector control; and
- mobilization of other sectors to incorporate dengue control into their goals and activities.

Diseases contracted through public water supplies

Populations vulnerable to water-borne diseases should have access to safe drinking water. Cryptosporidium oocysts are resistant to chlorine and other disinfectants and have a very low sedimentation rate (Medema et al., 1998; Venczel et al., 1997). Consequently, boiling may be the most appropriate method of disinfecting water where risks of infection exist (Willocks et al., 1998). The use of submicrometre point-of-use filters may reduce the risk of waterborne cryptosporidiosis (Addiss et al., 1996). In addition, several simple and cheap techniques effectively reduce the risk of infection with cholera from contaminated water. A simple filtration procedure involving the use of domestic material can reduce the number of vibrios attached to plankton in raw water (Huo et al., 1996). In Bolivia, the use of a 5% calcium hypochlorite solution to disinfect water and the subsequent storage of the treated water in a narrow-mouthed jar produced drinking water from non-potable sources that met the WHO standards for microbiological quality (Quick et al., 1996). These examples of low cost technologies should become widely available to populations which are likely to be affected by contaminated water supplies, for example, following flooding.

5.6 National nutrition action plans

Hunger and malnutrition are already among the most devastating problems facing nations. Nearly 30% –of infants, children, adolescents, adults and elderly people in the developing world are currently suffering from one or more of the multiple forms of malnutrition. National governments have recently adopted the World Declaration and Plan of Action for Nutrition at the International Conference of Nutrition (WHO, 1996). The declaration identifies nine goals and strategies as global priority nutrition action areas. The first two objectives are to reduce famine-related deaths, starvation and nutritional deficiency diseases in communities affected by natural and human-made disasters.

Most of WHO's nutrition activities — whether concerning micronutrient deficiencies, protein-energy malnutrition, infant and young child feeding, obesity, nutrition and ageing, or development of food-based dietary guidelines—are incorporated by governments into national nutrition policies or plans of action for nutrition. In the World Declaration and Plan of Action for Nutrition, countries are mandated to develop and implement coherent national plans and policies in order to tackle nutritional problems in a comprehensive manner. Countries should also consider the impact of future global environmental changes that affect nutrition, particularly, global climate change within a comprehensive national food policy.

6. Enhancing Adaptive Capacity

All strategies mentioned above are either part of the public health sector or need intersectoral adaptation and cross-sectoral adaptation measures. Most primary preventive measures are only achievable through intersectoral and cross-sectoral collaboration. Trends in inequality, resource consumption and depletion, environmental degradation, population growth and ill-health are closely inter-related and will strongly interact with potential climate change impacts (Dasgupta, 1995; Petersen et al., 1998). Measures to combat those underlying driving forces need to be considered by all sectors. Capacity building is an essential step in preparing sustainable adaptation and mitigation strategies. It includes education, awareness raising and the creation of legal frameworks, institutions and an environment that enables people to take well-informed decisions for the long-term benefit of their society. Women, youth, nongovernmental organizations, professional and nonprofessional associations, need to be brought into capacity building strategies, as they are essential in building a sustainable future.

6.1. Intersectoral collaboration

Integrated water management

Intersectoral collaboration is essential for the management of all resources. Climate change, population growth, increased economic activities and increased demand are likely to impinge on available natural resources, of which water is one of the most important.

The holistic management of freshwaters as a finite and vulnerable resource, and the integration of sectoral water plans and programs within the framework of national economic and social policy are of paramount importance for action in the 1992 and beyond. (UNCED, 1992)

The implementation of chapter 18 of Agenda 21 of the United Nations Conference on Environment and Development for the sustainable use of the world's water resources requires intersectoral action at international, regional and local levels. Examples of actions in low- and high-income countries with low or high water stresses are described in Table 6.1.

Integrated environmental management

The incidence of certain water-borne and vector-borne infections can be reduced by several environmental measures. Experience with the WHO/FAO/UNEP/UNCHS Panel of Experts on Environmental Management (PEEM) has shown that early consultations between health and agricultural sectors can greatly reduce the burden of vector-borne diseases (e.g. malaria and schistosomiasis) in large-scale irrigation projects (FAO, 1987). Climate change is likely to amplify the challenge of pest control because new ecological niches will appear that may sustain exotic pathogens and disease vectors. The recent establishment of the Environmental Risk Management Authority (ERMA) in New Zealand is an example of a strategy of collaboration between the health, forestry, environment, and conservation sectors (Anon, 1996). New Zealand is particularly vulnerable to invading species. ERMA provides an integrated approach with a wide-ranging brief that includes regulation of importation, investigation of incidents and emergencies and review of existing hazards. The Authority has formal links with many sectors, must consider public input from diverse interest groups, and reports directly to a senior Minister who holds both the Environment and Biosecurity portfolios.

Urban planning

Current strategies to reduce poverty and vulnerability to climate variability in urban environments will serve to enhance adaptation to the health impacts of climate change. For example, strategies to reduce the urban heat-island effect include: improved insulation of buildings; design features that reduce heat load; planting trees; and the use of materials with high albedo for roads, parking lots and roofs. Urban slum populations are particularly vulnerable to extreme events. Adequate building codes and urban infrastructure should be built to withstand extreme events. Infrastructures for removal of solid waste and wastewater and to supply potable water are essential. An often-neglected consideration in the design of sewerage systems is the performance of the major drainage system, including flows over land and in streets, during major floods. New design approaches, which explicitly design roads to act as drains, can radically reduce the duration of flooding.

TABLE 6.1.
ACTIONS REQUIRED IN LOW AND HIGH INCOME COUNTRIES TO IMPROVE WATER QUALITY AND AVAILABILITY

	Low water stress*	High water stress*
High income countries	● Pollution reduction ● Water pricing ● Demand management measures and water right markets	● Demand management and water allocation policies ● Protection of surface and groundwater from pollution ● Waste water treatment and reuse
Low income countries	● Sanitation and waste water treatment and reuse ● Pollution monitoring and control policies	● Economic and regulatory measures designed to increase irrigation efficiency and optimise water allocation ● Develop educational and information infrastructure ● Shift to less water-intensive crops ● Food imports ● Waste water treatment and reuse

Source: UN/UNDP/UNEP/FAO/UNESCO/World Bank/WHO/UNIDO/SEI, 1997

<u>Water scarcity</u> occurs when the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, bringing about increased competition among potential demand.

<u>Water stress</u> is the ratio of water withdrawal to water availability on an annual basis. Four categories of water stress are distinguished: Low water stress, moderate, medium high and high water stress. High water stress is when more than 40 % of available water indicates serious scarcity, and usually an increasing dependency on desalination and use of groundwater faster than it is replenished. This means that there is an urgent need for intensive management of supply and demand. Present use patterns and withdrawal may not be sustainable, and water scarcity can become the limiting factor for economic growth. Low water stress is when countries use less than 10% of their available freshwaters.

6.2. Partnerships with the private sector

There is a need for increased collaboration between the different public and private sectors for building partnerships with the private sector. The recent launch by WHO of the Medicines for Malaria Venture – a joint initiative by the public and private sectors to develop new antimalarial drugs – is an example of collaboration in developing new products for use in developing countries. Another example is the donation of drugs by industry to help eliminate infectious diseases with a high disease burden in developing countries. Vaccine manufacturers have also occasionally donated vaccines during outbreaks of disease, for polio eradication, and for vaccine trials in developing countries (WHO, 1999b). Joint activities with the insurance and tourist sectors could also be developed.

6.3. Technological development and capacity

Technological development and capacity directly reflect economic conditions and cultural values. However, the lack of investment in equipment, transport systems and skilled personnel might lead, for example, to outbreaks of vaccine-preventable diseases. Interruption of the vaccine cold chain is one of the reasons for ineffective vaccination campaigns.

6.4 Adequate expenditure on health care and prevention

Equity of access to health care, public health infrastructure, adequate expenditure for health care and prevention programmes are fundamental needs for adaptation to climatic change. As long as people have access to health care and adequate public health control programmes are available, the resurgence of some infectious diseases can be limited.

The economic crises of the 1980s, in addition to poor policy decisions in the late 1960s and 1970s, have led to cuts in both government and household expenditures on health in many developing countries and countries of the former Union of Soviet Socialist Republics (Evlo and Carrin, 1992). Effective medicines and control strategies are available to reduce dramatically the deaths and suffering caused, for example, by infectious diseases. Yet, many governments are failing to ensure that these strategies receive enough funding to succeed. In some cases, this is because health budgets are unrealistically small. In other cases, it is because health spending is poorly prioritized even for the most urgent health threats. Some of the poorest countries spend no more than $7 a head on health care annually, making it difficult to ensure that even the most basic health needs are met. On average, health expenditures in 1994 in low-income countries were $16 per capita. In contrast, average health expenditures in high-income countries were more than $1800 per capita (WHO, 1999a).

Low-income countries spend 4% of their gross domestic product (GDP) per capita on health, half the rate of wealthier countries. In many poor countries, spending is even lower. In Cameroon, Indonesia, Nigeria and Sri Lanka, for example, it is less than 2% of their GDP. Donor assistance has helped supplement underfunded health initiatives. However, resources available for such support are relatively small. Health, nutrition and population projects receive less than 5% of donor support, which is a fifth of the amount provided to energy, transportation and communications projects. Figure 6.1 shows world expenditure on health as a fraction of donor funding and total GDP.

In Viet Nam, a four-year strategy on malaria between 1992 and 1996 has reduced malaria deaths by over 90% and malaria cases by 40% (Figure 6.2). Health workers have succeeded through government commitment, increased funding, and the widespread use of locally-produced low-cost tools. Locally produced high-quality drugs are now being used to treat cases of severe and multidrug-resistant malaria. Throughout Viet Nam, about 12 million people are protected by house spraying and insecticide-impregnated bednets. In areas where malaria is endemic, insecticide impregnation is provided as a public service, free of charge. The success of the programme has attracted international funding, allowing the government to give funding to other control programmes.

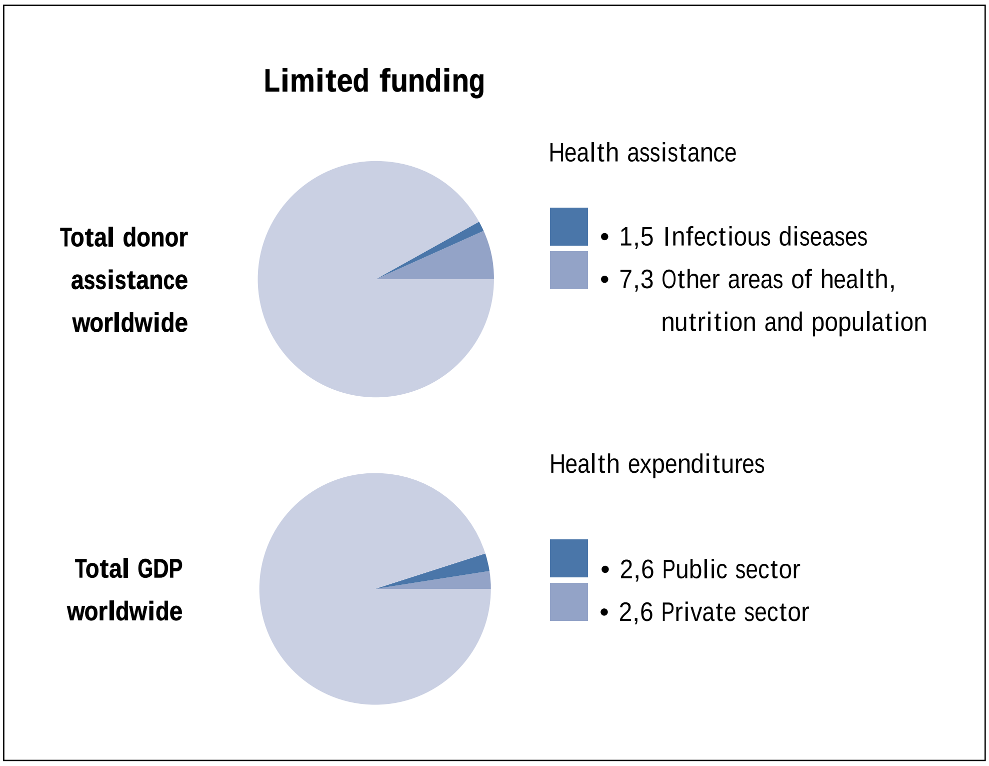


Figure 6.1 Health expenditure and health assistance

Source: WHO, 1999b

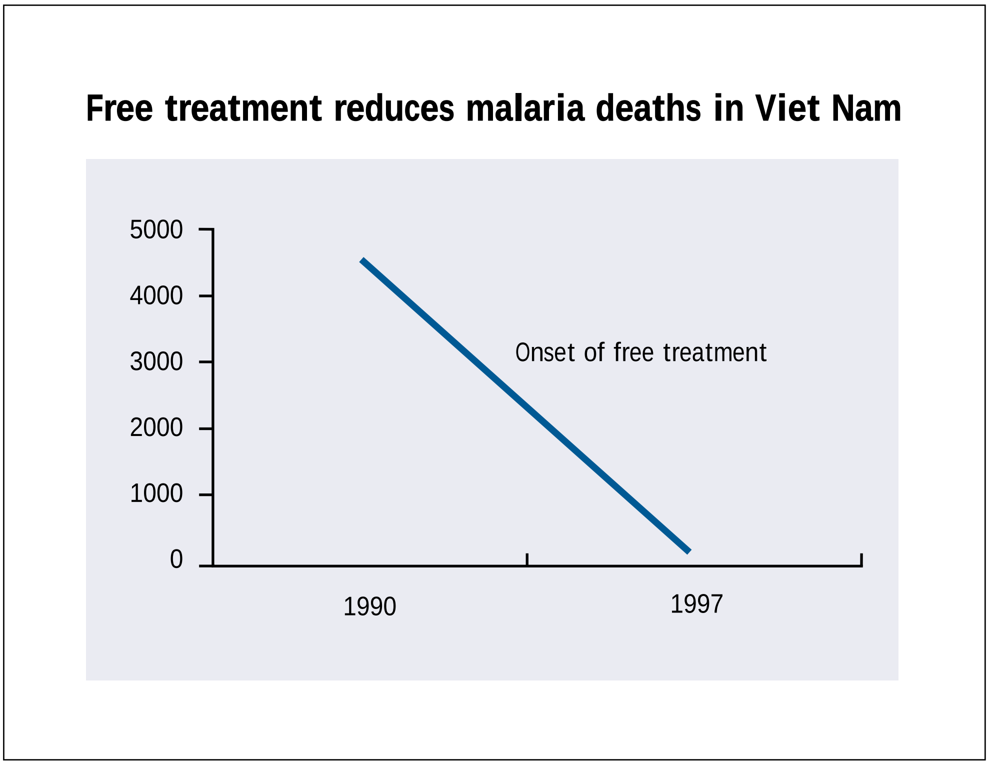


Figure 6.2 Free treatment reduces malaria deaths in Vietnam

Source: WHO, 1999b

6.5 Maladaptation - the need for climate- and health-friendly development

Policymakers need to address several dimensions of climate change. There are many opportunities to improve public health through the Clean Development Mechanism and "no-regrets policies" under the Climate Change Convention and the Kyoto Protocol (see McMichael et al., Health. In IPCC Special Report on Methodological and Technological Issues in Technology Transfer). There would be significant "ancillary" benefits from emissions reductions on local air pollution and associated mortality (Wang and Smith, 1999; Working Group on Public Health and Fossil Fuel Combustion, 1997).

When implementing adaptation technologies, care must be taken to prevent the occurrence of secondary impacts, that is, new health hazards created by the application of technologies (Klein and Tol, 1997). Water development projects have had significant effects on the local transmission of parasitic diseases including malaria, lymphatic filariasis and schistosomiasis. Measures to improve crop yields may include increased spraying of agrochemicals, which are an acknowledged health hazard. An integrated approach to environmental management that addresses health impacts is essential.

7. The role of WHO

WHO, like other specialized agencies of the United Nations, is primarily mandated to support government planning and management for health in its Member States. It also plays an important role in supporting countries in applying internationally agreed rules and regulations, and quality standards.

As a response to the requirements stated in Agenda 21 and the United Nations Framework Convention on Climate Change (UNFCCC), several organizations carrying out significant climate-related activities have jointly developed the Climate Agenda, a comprehensive and integrating framework on all aspects of international climate related programmes, including data collection and application, climate system research and studies of socioeconomic and health impacts of climate variability and their effects on ecosystems. The international organizations participating in the Climate Agenda include FAO, UNEP, UNESCO and its Intergovernmental Oceanographic Commission (IOC), WHO, WMO and the International Council of Scientific Unions. WHO's participation was endorsed at the Fifty-first World Health Assembly (resolution WHA 51.29).

The establishment of an Inter-Agency Network on Climate and Human Health, with a secretariat coordinated by WHO, to coordinate the relevant activities of the Climate Agenda, was discussed in the second session of the Inter-Agency Committee on the Climate Agenda (Geneva, 1998).

The proposed work focuses on three areas, as follows:

- Capacity building. Assisting Member States in: (a) undertaking national assessments of climate-induced human health impacts; (b) determining and meeting capacity-building and research needs in order to identify and address priority areas; (c) identifying and implementing adaptation strategies and preventive and mitigating measures designed to effectively reduce adverse health impacts.

- Information exchange work. Assisting Member States in (a) providing information on the state-of-the-art in the global research effort on climate and health interactions, their consequences for population health and for public health response, together with relevant national and international training and strengthening of research institutions; (b) fulfilling "clearinghouse" functions to ensure free access to information including databases needed for research on climate variability and climate change effects on human health in developing countries, in particular with regard to databases held in international agencies and in national institutions in developed countries..

- Research promotion. Serving as the United Nations-based lead group of institutions and

Table 7.1.
Recent publications on Climate and Health

Books:	● McMichael AJ, Haines A, Slooff R, Kovats RS, eds. (1996) *Climate Change and Human Health: an Assessment by a Task Group on behalf of the World Health Organization, the World Meteorological Organization and the United Nations Environment Programme.* Geneva, WHO [WHO/EHG/96.7] ● WHO, Regional Office for Europe (2000) Kovats RS, Menne B, McMichael AJ, Bertollini R, and Soskolne C, eds. *Early Human Health Effects of Climate Change in Europe.* Background Report for Third Ministerial Conference on Environment and Health, London 1999. Copenhagen, WHO Regional Publications, European Series.
Meeting reports:	● PAHO (1998) *The health impact of the El Niño phenomenon.* Central American workshop held in San Jose, Costa Rica, 3-5 November 1997. ● WHO/MRC/UNEP (1998) *First InterAgency Climate Change and Human Health Monitoring Workshop,* 14-15th October 1997. Medical Research Centre, London. ● World Health Organization Regional Office for Europe (1999). *Early human health effects of climate change : report of a WHO Workshop, Rome, Italy, 21-23 May 1998*, WHO Regional Office for Europe, Copenhagen, 1999. EUR/ICP/EHRO 02 05 02
Technical reports:	● PAHO (1998) *El Niño and its impact on health.* Report presented to 122nd Executive Assembly of PAHO May 1998. Document CE122/10. ● *Wang X, Smith K. Near-term Health Benefits of Greenhouse Gas Reductions: A proposed assessment method and application in two energy sectors of China*. Doc. No. WHO/SDE/PHE/99.1. WHO, 1999 ● Kovats RS, Bouma MJ and Haines A (1999) *El Niño and health.* Geneva, WHO Technical Report (WHO/SDE/PHE/99.4). ● WMO (1996) *Climate and Human Health* prepared by WMO/WHO/UNEP in 96. Published by WMO (WMO-No.843).
Journal articles:	● Bertollini, R., Menne, B. (1998) Early health effects of climate change in Europe. European Bulletin on Environment and Health, 1998, 5 (3), pp. 5-6 ● Bertollini, R., Menne, B. (1999) Climate change: what consequences? Naturopa, 90 ● Kovats RS, Haines A, Stanwell-Smith R, Martens P, Menne B, Bertollini R (1999) Climate change and health in Europe. British Medical Journal, 1999, 328 (7199) ● Menne B (2000) Can the health sector adapt to climate variability/change? In: European bulletin on environment and health, 7 (2). Copenhagen, WHO Regional Office for Europe. ● Menne B, Bertollini R.(1999) "Climate Change and Health" In: European bulletin on environment and health. Copenhagen, WHO Regional Office for Europe, 6 (4) ● Menne B, Pond K, Noji EK and Bertollini R (1999). Floods and public health consequences, prevention and control measures. Discussion paper presented at the UNECE Seminar on flood prevention, Berlin, 7-8 October 1999 (UNECE/MP.WAT/SEM.2/1999/22) ● Menne B., Bertollini R. (1999) The health effects of climate variability/change in the mediterranean area. Epidemiology, 10 (4 Suppl), 1999, p. S152 ● Menne B., Kovats S, Bertollini R., Soskolne C. (1999) Methods for climate change health impacts assessment. Epidemiology, 10 (4 Suppl), 1999, p. S154

experts for the guidance of research programmes on the human health implications of climate and on global environmental change, including the impacts of climate variability, climate change and stratospheric ozone depletion.

A first step was taken in the WHO European region, where seventy-one European Ministers for Environment and Health welcomed at the Third Ministerial Conference on Environment and Health (London, 1999) the recommendations on "the early health effects of climate change and stratospheric ozone depletion". These include:

- the setting up of a Europe-wide interagency network for monitoring, researching and reviewing the early human health effects of climate change and of stratospheric ozone depletion, developing and advocating prevention, mitigation and adaptation policies, and identifying specific research priorities in that field;

- the support of the identification, development, standardization, evaluation and broad use of systems for monitoring and assessing changes in environmental indicators, bio-indicators of health risk and impacts on health as well as indicators of population health status across Europe. These systems must be coordinated with global monitoring activities;

- the development of capacities, as necessary, to undertake national health impact assessments with the aim of identifying the vulnerability of populations and subgroups and will ensure the necessary transfer of know-how among countries; and

- the review of the social, economic and technical prevention, mitigation and adaptation options available to reduce the adverse impacts of climate change and stratospheric ozone depletion on human health.

Recent publications on climate and health are listed in Table 7.1. WHO emphasizes the importance of people at the centre of development and the crucial role of health as a contributor to development. Policies for sustainable development need to be built upon open dialogue with member states and intergovernmental bodies as well as other partners, such as nongovernmental organizations that play important roles in global environment and health issues. Intersectoral collaboration is one of the guiding principles of the WHO's Health 21 strategy.

8. Conclusions

At the beginning of the 21st century, society faces a complex set of environmental problems impacting directly or indirectly on health. Some act on a global scale, such as issues related to stratospheric ozone depletion, loss of biodiversity, and increasingly the potential problems resulting from climate change.

- Climate change can have an adverse impact on the availability and quality of fresh water supply, and on efficiency of local sewerage systems. The potential health impacts are considerable.

- Climate change may have impacts on the yield of cereals grains, with increases at high and mid latitudes but decreases at lower latitudes. Changes in food production are likely to have a significant impact health in Africa.

- The distribution and seasonality of several vector-borne infectious diseases (such as malaria, dengue and dengue haemorrhagic fever) are likely to be affected by climate change. Altered distribution of some vector species may be among the early signs of environmental impacts resulting from climate change, which in turn will result in health impacts. Early warning indicators need to be identified and used.

- A change in world climate could increase the frequency and severity of heatwaves. This is particularly a problem in urban areas, where excess mortality and morbidity is currently observed during hot weather episodes.

- A variety of methods have been developed for the quantitative estimation of the health impacts of future climate change. In spite of many uncertainties, the estimation of the potential burden of disease (in terms of death, disease and disability) due to climate change is necessary in order to allow decision-makers to assess the potential magnitude of the problem in health terms, and to aid the decision-making process in the area of adaptation. Cost estimates, including cost effectiveness analyses are also required for this purpose.

Health impacts of global environmental changes, including climate, are likely to have an unequal impact on population groups: the poor and marginalized groups are at greatest risk because of limited resources which in turn limit their ability to adapt.

- In natural disasters, for example, the vulnerability of those living in risk-prone areas is an important contributor to disaster casualties and damage. Some 90% of disaster victims world-wide live in developing countries.

- Adaptation is a key response strategy to minimize potential impacts of climate change.

- A primary objective of adaptation is the reduction, with the least cost, of death, disease, disability and human suffering. The ability to adapt to climate change impacts, and specifically of health, will depend on many factors including existing infrastructure, resources, technology, information and the level of equity in different countries and regions.

Intersectorial policies which promote ecologically sustainable development and address the underlying driving forces will be essential in managing health impacts and adaptation measures.

- Strategies to deal with the impacts of climate change on health need intersectoral and cross-sectoral adaptation measures and collaboration. The health sector alone, or limited collaboration between a few sectors, cannot deal with the necessary "primary" adaptation measures to respond to climate change.

- Carefully selected indicators related to "climate-environmental" health are needed to monitor the situation at regional and national levels.

- Effective response to information from surveillance systems requires a strong public health infrastructure together with a well-informed and active local community.

- Capacity building is an essential step for adaptation and mitigation strategies. This should include education, training and awareness raising, as well as the creation of legal frameworks, institutions and an environment that enables people to take well-informed decisions for the long-term benefit of society.

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