

Protecting **Health**
from **Climate Change**

WORLD HEALTH DAY 2008



**World Health
Organization**

WHO Library Cataloguing-in-Publication Data

Protecting health from climate change - World Health Day 2008

1.Climate - trends. 2.Environmental health. 3.Meteorological factors. 4.Risk management.
5.Disaster planning. 6.Forecasting. 7.Ecosystem. 8.Anniversaries and special events.
I.World Health Organization.

ISBN 978 92 4 159652 7

(NLM classification: WA 30)

© World Health Organization 2008

All rights reserved. Publications of the World Health Organization can be obtained from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int). Requests for permission to reproduce or translate WHO publications – whether for sale or for noncommercial distribution – should be addressed to WHO Press, at the above address (fax: +41 22 791 4806; e-mail: permissions@who.int).

The designations employed and the presentation of the material, including maps, in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

CONTENTS

Statement by the Director-General of the World Health Organization	01
Summary	02
WHAT ARE THE RISKS?	
1. Climate change: past and future	04
2. Climate and its impact on the fundamentals of health	06
3. “Natural” disasters: the growing influence of climate change on heatwaves, floods, droughts and storms	08
4. Changing patterns of infection	10
5. Long-term stresses: water shortages, malnutrition, displacement and conflict	12
WHO IS AT RISK?	
6. Vulnerable regions: exposed populations	14
7. Children: life-long exposure to health risks from climate change	16
8. The most vulnerable: they support the greatest health burdens	18
9. All of us: our shared health security	20
WHAT NEEDS TO BE DONE?	
10. Putting health at the heart of the climate change agenda	22
11. Strengthening public health systems	24
References	



STATEMENT BY THE DIRECTOR-GENERAL OF THE WORLD HEALTH ORGANIZATION

Last year marked a turning point in the debate on climate change. The scientific evidence continues to mount. The climate is changing, the effects are already being felt, and human activities are a principal cause.

In selecting climate change as the theme for this year's World Health Day, WHO aims to turn the attention of policy-makers to some compelling evidence from the health sector. While the reality of climate change can no longer be doubted, the magnitude of its consequences – especially for health – can still be reduced. Consideration of the health impact of climate change can help political leaders move with appropriate urgency.

The core concern is succinctly stated: climate change endangers health in fundamental ways.

The warming of the planet will be gradual, but the effects of extreme weather events – more storms, floods, droughts and heatwaves – will be abrupt and acutely felt. Both trends can affect some of the most fundamental determinants of health: air, water, food, shelter, and freedom from disease.

Although climate change is a global phenomenon, its consequences will not be evenly distributed. Scientists agree that developing countries and small island nations will be the first and hardest hit.

WHO has identified five major health consequences of climate change.

First, the agricultural sector is extremely sensitive to climate variability. Rising temperatures and more frequent droughts and floods can compromise food security. Increases in malnutrition are expected to be especially severe in countries where large populations depend on rain-fed subsistence farming. Malnutrition, much of it caused by periodic droughts, is already responsible for an estimated 3.5 million deaths each year.

Second, more frequent extreme weather events mean more potential deaths and injuries caused by storms and floods. In addition, flooding can be followed by outbreaks of diseases, such as cholera, especially when water and sanitation services are damaged or destroyed. Storms and floods are already among the most frequent and deadly forms of natural disasters.

Third, both scarcities of water, which is essential for hygiene, and excess water due to more frequent and torrential rainfall will increase the burden of diarrhoeal disease, which is spread through contaminated food and water. Diarrhoeal disease is already the second leading infectious cause of childhood mortality, and accounts for a total of around 1.8 million deaths each year.

Fourth, heatwaves, especially in urban “heat islands”, can directly increase morbidity and mortality, mainly in elderly people with cardiovascular or respiratory disease. Apart from heatwaves, higher temperatures can increase ground-level ozone and hasten the onset of the pollen season, contributing to asthma attacks.

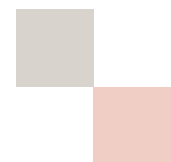
Finally, changing temperatures and patterns of rainfall are expected to alter the geographical distribution of insect vectors that spread infectious diseases. Of these diseases, malaria and dengue are of greatest public health concern.

In short, climate change can affect health problems that are already huge, largely concentrated in the developing world, and difficult to combat.

On this World Health Day, I am announcing increased WHO efforts to respond to these challenges. WHO and its partners are devising a research agenda to obtain better estimates of the scale and nature of health vulnerability and to identify strategies and tools for health protection. WHO recognizes the urgent need to support countries in devising ways to cope. Better systems for surveillance and forecasting, and stronger basic health services, can offer health protection.

Citizens, too, need to be fully informed of the health issues. In the end, it is their concern that can spur policy-makers to take the right actions, urgently.

Dr Margaret Chan
Director-General
World Health Organization



SUMMARY

Climate change puts at risk the basic determinants of health

There is now widespread agreement that the earth is warming, due to emissions of greenhouse gases caused by human activity. It is also clear that current trends in energy use development and population growth will lead to continuing – and more severe – climate change.

The changing climate will inevitably affect the basic requirements for maintaining health: clean air and water, sufficient food and adequate shelter. Each year, about 800 000 people die from causes attributable to urban air pollution, 1.8 million from diarrhoea largely resulting from lack of access to clean water supply and sanitation, and from poor hygiene, 3.5 million from malnutrition and approximately 60 000 in natural disasters. A warmer and more variable climate threatens to lead to higher levels of some air pollutants, increase transmission of diseases through unclean water and through contaminated food, to compromise agricultural production in some of the least developed countries, and to increase the hazards of extreme weather.


Climate change also brings new challenges to the control of infectious diseases. Many of the major killers are highly climate sensitive as regards temperature and rainfall, including cholera and the diarrhoeal diseases, as well as diseases including malaria, dengue and other infections carried by vectors. In sum, climate change threatens to slow, halt or reverse the progress that the global public health community is now making against many of these diseases.

In the long run, however, the greatest health impacts may not be from acute shocks such as natural disasters or epidemics, but from the gradual build-up of pressure on the natural, economic and social systems that sustain health, and which are already under stress in much of the developing world. These gradual stresses include reductions and seasonal changes in the availability of fresh water, regional drops in food production, and rising sea levels. Each of these changes has the potential to force population displacement and increase the risks of civil conflict.

All populations are vulnerable – but some are more vulnerable than others

All populations will be affected by a changing climate, but the initial health risks vary greatly, depending on where and how people live. People living in small island developing states and other coastal regions, megacities, and mountainous and polar regions are all particularly vulnerable in different ways.

Health effects are expected to be more severe for elderly people and people with infirmities or pre-existing medical conditions. The groups who are likely to bear most of the resulting disease burden are children and the poor, especially women. The major diseases that are most sensitive to climate change – diarrhoea, vector-borne diseases like malaria, and infections associated with undernutrition – are most serious in children living in poverty.



We have a common interest in facing up to health risks wherever they occur. Ongoing climate change, coupled with globalization, will make it more difficult to contain infectious diseases within their current ranges. Health challenges arising from population displacement and conflict are unlikely to stay confined within national borders. Improved health conditions for all populations, alongside more rapid and effective international disease surveillance, constitute a vital contribution to global public health security.

Protecting human health is the “bottom line” of climate change strategies

Climate change can no longer be considered simply an environmental or developmental issue. More importantly, it puts at risk the protection and improvement of human health and well-being. A greater appreciation of the human health dimensions of climate change is necessary for both the development of effective policy and the mobilization of public engagement.

Strengthening of public health services needs to be a central component of adaptation to climate change. The international health community already has a wealth of experience in protecting people from climate-sensitive hazards, and proven, cost-effective health interventions are already available to counter the most urgent of these. Broadening the coverage of available interventions would greatly improve health now. Coupled with forward planning, it would also reduce vulnerability to climate changes as they unfold in the future.

The diverse, widespread, long-term and inequitable distribution of health risks makes climate change a truly global challenge, calling for an unprecedented degree of partnership. An effective response will require actions from across society: from individuals, the health sector, and community and political leaders. A fair and effective response will require a sharing of responsibilities between the populations that make the greatest contribution to climate change and those that are most vulnerable to its effects, in order to safeguard and enhance global public health security.

WHAT ARE THE RISKS?

1. Climate change: past and future

The basic facts are now firmly established. The earth is warming rapidly, mainly because of emissions of greenhouse gases caused by human activity. If current patterns of fossil fuel use, development and population growth continue, this will lead to ongoing climate change, with serious effects on the environment and, consequently, on human lives and health.

CLIMATE CHANGE IS HAPPENING NOW. Warming of the global climate is unequivocal and is shown by increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Eleven of the twelve years during the period 1995–2006 rank among the twelve warmest years in the instrumental record of global surface temperature that dates back to 1850.

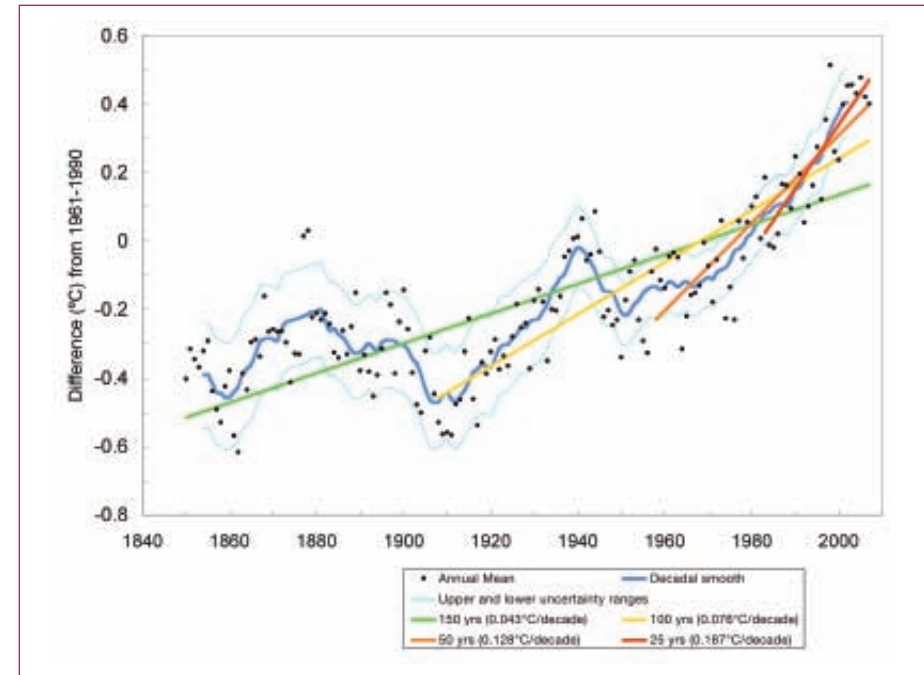
GLOBAL WARMING HAS ACCELERATED IN RECENT YEARS. The world warmed by approximately 0.75°C in the last 100 years (see Figure 1a). The rate of increase in the last 25 years, however, is much higher, at over 0.18°C per decade. This temperature increase is widespread over the globe, with land regions warming faster than the oceans.

SEA LEVELS ARE RISING, GLACIERS ARE MELTING AND PRECIPITATION PATTERNS ARE CHANGING. Sea levels have risen faster in the last decade than in the previous 30 years. On average, there has been a global reduction in mountain glaciers and snow cover. From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia, but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, it is likely that the area affected by drought has increased since the 1970s.

EXTREME WEATHER EVENTS ARE CHANGING IN FREQUENCY AND INTENSITY. It is considered that heatwaves have become more frequent over most land areas, the frequency of heavy precipitation events has increased

Figure 1 (a). Global temperature rise.

Annual global mean temperatures and decadal variations for the period 1850–2005, with linear trends for the last 25, 50, 100 and 150 years.



Source: based on data from the UK Hadley Research Centre.²

over most areas and, since 1975, sea level has risen worldwide. There is also some evidence that intense tropical cyclone activity has increased since 1970.

HUMAN ACTIVITIES ARE NOW THOUGHT TO BE THE MAIN CAUSE OF THE CHANGING CLIMATE. Most of the observed increase in temperatures since the mid-20th century is very likely to be attributable to the increase in

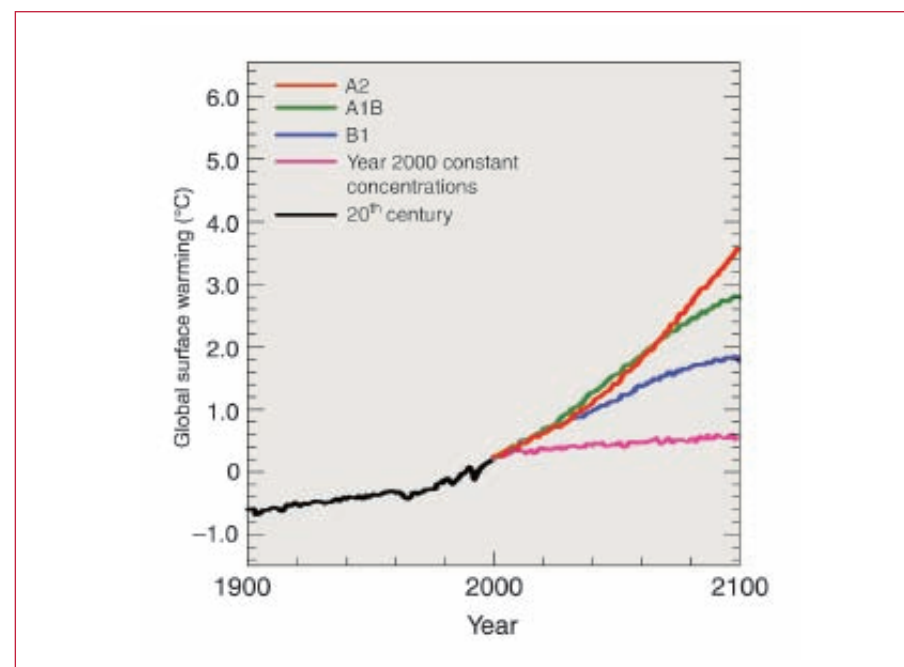
concentrations of greenhouse gases released by human activities, mainly carbon dioxide (CO₂) emitted by burning of fossil fuels. Levels of carbon dioxide have increased from pre-industrial levels of 280 parts per million to 379 parts per million.

CONTINUED WARMING COULD LEAD TO ABRUPT OR IRREVERSIBLE IMPACTS. Melting of ice sheets on polar land could cause several metres of sea level rise, with major inundation of low-lying areas. Drying and burning of the Amazon basin, and warming of peat bogs, could release large amounts of greenhouse gases, further accelerating climate change.

HUMAN-INDUCED CLIMATE CHANGE WILL CONTINUE FOR AT LEAST THE NEXT FEW DECADES. Even if emissions of greenhouse gases were to halt immediately, temperatures would be expected to rise by about 0.6 °C over in this century. The development paths that the world chooses, however, will have a strong influence on this increase (see Figure 1b). In a world that places high priority on sustainable energy use, temperatures are expected to rise by 1.8°C (likely range: 1.1–2.9°C). If societies place a lower emphasis on sustainability, temperatures are expected to rise by 4.0°C (2.4–6.4°C), with a greater probability of abrupt or irreversible impacts.¹

Figure 1 (b). Projected global temperature rise in the 21st century.

Projected temperature changes (relative to 1980-1999) in selected development scenarios, from lower emphasis on sustainable development and cooperation (A2) to greater attention to environmental protection and regional integration (B1). The orange line is the projection assuming greenhouse gas concentrations were held constant at year 2000 values.



Source: IPCC, 2007.¹





2. Climate and its impact on the fundamentals of health

Climate change will affect, in profoundly adverse ways, some of the most fundamental pre-requisites for good health: clean air and water, sufficient food, adequate shelter and freedom from disease. The global climate is now changing faster than at any point in human civilization, and many of the effects on health will be acutely felt. The most severe risks are to developing countries, with negative implications for the achievement of the health-related Millennium Development Goals and for health equity.

EXTREME AIR TEMPERATURES AND AIR POLLUTION ARE HAZARDOUS TO HEALTH. Heatwaves are a direct contributor to deaths from cardiovascular and respiratory disease, particularly among elderly people. High temperatures also raise the levels of ozone and other air pollutants that exacerbate cardiovascular and respiratory disease, and pollen and other aeroallergens that trigger asthma.

FLOODS, DROUGHTS AND CONTAMINATED WATER RAISE DISEASE RISK. More variable precipitation is occurring, with an increase in the frequency and intensity of both floods and droughts. At the same time, higher temperatures are hastening rates of evaporation of surface waters and melting the glaciers that provide fresh water for many populations. Lack of fresh water compromises hygiene, thus increasing rates of diarrhoeal disease. In extreme cases, water scarcity results in drought and famine. Too much water, in the form of floods, causes contamination of freshwater supplies and also creates opportunities for breeding of disease carrying insects such as mosquitoes.

CLIMATIC EFFECTS ON AGRICULTURE THREATENS INCREASING MALNUTRITION. Rising temperatures and changing patterns of rainfall are projected to decrease crop yields in many developing countries, stressing food supplies.³ For populations that depend on subsistence farming, or do not have sufficient income to buy food, this situation is expected to translate

directly into wider prevalence of malnutrition. In turn, malnutrition and undernutrition increase the severity of many infectious diseases, particularly among children.

A MORE EXTREME AND VARIABLE CLIMATE CAN DESTROY HOMES, COMMUNITIES AND LIVES. Expected increases in the frequency and severity of flooding and storms will result in the destruction of homes, medical facilities and other essential services, impacting particularly on people in slums and other marginal living conditions. Gradual sea level rise, particularly coupled with stronger storm surges, will tend to lead to more frequent and more severe coastal flooding. The consequent destruction of homes and communities will eventually force unprotected populations to seek safer ground, often increasing environmental and social pressures in their new locations.

CLIMATE CHANGE BRINGS NEW CHALLENGES TO THE CONTROL OF INFECTIOUS DISEASES. Many of the major killer diseases transmitted by water and contaminated food, and by insect vectors are highly sensitive to climatic conditions and weather extremes. Climate change threatens to slow, halt or reverse current progress against many of these infections.

NOT ALL OF THE EFFECTS OF CLIMATE CHANGE WILL BE HARMFUL, BUT ON BALANCE HEALTH DAMAGES ARE PROJECTED TO OUTWEIGH THE BENEFITS. A warmer climate is expected to bring benefits to some populations, including reduced mortality and morbidity in winter and greater local food production, particularly in northern high latitudes. However, projections by WHO⁴ and IPCC⁵ suggest that the negative effects of climate change on health are greater and are more strongly supported by evidence than are the possible benefits (see Box 1). In addition, the negative effects are concentrated on poor populations that already have compromised health prospects, thus widening the inequality gap between the most and the least privileged.



UNEP / Still pictures



WHO / Benoist Mabele-Carpentier



Laurent Weyl / ARGOS



Thorikell Thorkeisson / Icelandic Red Cross



WHO / Madeline Decker

Climate and weather affect the fundamental determinants of health. From left: air quality in China, food availability in Mali, fresh water in Bangladesh, infection in Cambodia, shelter in Angola.

Box 1. Climate change and the determinants of health: facts and figures

Air. Extreme high air temperatures can kill directly; it has been estimated that more than 70 000 excess deaths were recorded in the extreme heat of summer 2003 in Europe.⁶ By the second half of this century, such extreme temperatures will be the norm.⁷ In addition, rising air temperatures will increase levels of important air pollutants such as ground-level ozone, particularly in areas that are already polluted. Urban air pollution currently causes about 800 000 deaths each year,^{4,8} mainly by increasing mortality from cardiovascular and respiratory diseases. The effects of just a 1°C rise in temperature on ozone and particulate levels may increase global deaths from air pollution by over 20 000 per year.⁹

Water. Shifting rainfall patterns, increased rates of evaporation and melting of glaciers, combined with population and economic growth, are expected to increase the number of people living in water-stressed water basins from about 1.5 billion in 1990 to 3–6 billion by 2050.¹⁰ By the 2090s, climate change may bring a doubling in the frequency of extreme drought events, a six-fold increase in mean duration, and a 10–30-fold increase in the land area in extreme drought.¹¹ Almost 90% of the burden of diarrhoeal disease is attributable to lack of access to safe water, sanitation,^{4,12} and reductions in the availability and reliability of freshwater supplies are expected to amplify this hazard.

Food. Increasing temperatures and more variable precipitation are expected to reduce crop yields in many tropical developing regions. In some African countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020.¹³ This is likely to aggravate the burden of undernutrition in developing countries, which currently causes 3.5 million deaths each year, both directly through nutritional deficiencies and indirectly by intensifying vulnerability to diseases such as malaria and diarrhoeal and respiratory infections.¹⁴

Shelter. By the second half of this century, climate change is projected to cause a several-fold increase in the frequency of extreme storms, heavy rainfall and heat-waves. In the absence of improvements to protection, by 2080 sea level rise could also multiply the number of people exposed to coastal flooding more than 10-fold, to more than 100 million people a year.¹⁵ These trends will also increase the hazards of weather-related natural disasters, which killed approximately 600 000 people during the 1990s.¹⁶ Repeated floods and droughts may force population displacement – which, in turn, is associated with heightened risks of a range of health effects, from mental disorders such as depression to communicable diseases and, potentially, civil conflict.

Freedom from disease. Rising temperatures, shifting rainfall patterns and increasing humidity affect the transmission of diseases by vectors and through water and food. Vector-borne diseases currently kill over 1.1 million people a year, and diarrhoeal diseases 1.8 million.¹⁷ Studies suggest that climate change may swell the population at risk of malaria in Africa by 90 million by 2030,¹⁸ and the global population at risk of dengue by 2 billion by the 2080s.¹⁹

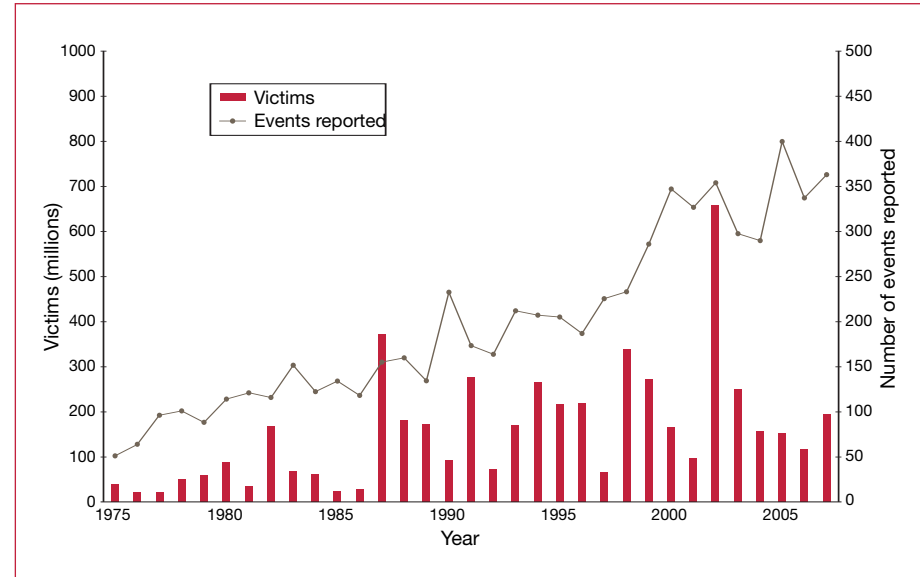
3. “Natural” disasters: the growing influence of climate change on heatwaves, floods, droughts and storms

Globally, the number of reported weather-related natural disasters is mounting rapidly. Reports of natural catastrophes have more than tripled since the 1960s. In 2007, 14 out of 15 “flash appeals” for emergency humanitarian assistance were for floods, droughts and storms – five times higher than in any previous year.²⁰

MORE NUMEROUS REPORTS OF NATURAL DISASTERS ARE PARTLY DUE TO POPULATION GROWTH IN HIGH-RISK AREAS, BUT IT IS POSSIBLE THAT CLIMATE CHANGE IS ALSO A CONTRIBUTING FACTOR. The last few decades have seen rapid growth in populations living in flood plains and coastal areas, particularly in developing country cities, placing more people in the path of weather-related natural disasters. At the same time, climate change has furthered the probability of extreme high temperatures and has probably contributed to more frequent and extreme precipitation events and more intense tropical cyclone activity.¹ Together, these trends will increase weather-related hazards to human health.

EXTREME HEAT. Studies from around the world have shown that temperatures above a locally specific threshold result in higher mortality rates. The extended hot summer of 2003 in Europe produced sustained record high temperatures which resulted in markedly higher death rates, particularly among the elderly population. In total, it has been estimated that 70 000 more deaths occurred in western Europe during that extreme summer than would have been expected for the time of year.⁶ Continuing global warming and possible increases in temperature variability²¹ will make such events more frequent – and more severe. It is expected that European summer temperatures as high as those experienced in 2003 will be the norm by the middle of the century.⁷

Figure 2. Number of weather-related disasters, and number of victims during 1975–2007, reported to the International Disaster Database, EM-DAT.



Source: EM-DAT, 2008.²⁴

FLOODS AND DROUGHTS. Even small changes in average precipitation can have a very large effect on the extremes of rainfall events that cause either flooding or drought, already the most frequent and deadly forms of natural disasters. For example, studies have shown that human influence on the global climate is likely to make what would currently be considered a “very wet winter” in the United Kingdom, or a “very wet summer” in the South Asian monsoon region, about five times more frequent by the second half of this century.²² Globally, climate change is likely to widen the area affected by drought, with particularly severe impacts in areas that are already water-stressed. These trends will impact on lives and on health. Floods cause drownings and physical injuries; heighten the risk of diseases



WHO / Paul Glendell

Flooding in the United Kingdom: intense precipitation is becoming more common over many areas.

transmitted through water, insect vectors and rodents; damage homes; and disrupt the supply of essential medical and health services. The number of floods reported globally is rising rapidly – much more rapidly than disasters unrelated to weather conditions (see Figure 2). Droughts increase the risk of food shortages and malnutrition. They also increase the risk of diseases spread by contaminated food and water.

TROPICAL STORMS. Extreme winds, particularly in the tropical regions, bring death and destruction. There is evidence for a marked increase in the numbers of the most extreme cyclones in recent decades, and this trend is likely to continue. Studies indicate that a doubling of the level of carbon dioxide in the atmosphere, expected within about 80 years, will result in an increase of only about 6% in average cyclone windspeed but of 300% in the frequency of the largest (category 5) storms.²³



4. Changing patterns of infection

Infections caused by pathogens that are transmitted by insect vectors are strongly affected by climatic conditions such as temperature, rainfall and humidity. These diseases include some of the most important current killers: malaria, dengue and other infections carried by insect vectors, and diarrhoea, transmitted mainly through contaminated water.

MALARIA DISTRIBUTIONS ARE STRONGLY AFFECTED BY CLIMATE. Transmitted by *Anopheles* mosquitoes, malaria is the most important vector-borne cause of mortality globally. It kills almost 1 million people each year, mainly poor children in Africa.¹⁷ Malaria is strongly influenced by climatic conditions; it is not transmitted in the cooler temperatures associated with high altitudes and latitudes, and the number of mosquito vectors depends on the availability of freshwater breeding sites. Warmer temperatures, higher humidity and more places where water can collect generally favour malaria transmission. There is evidence that in some sites in the highlands of East Africa, a warming trend over the last 30 years has improved conditions for mosquitoes, increasing the probability of malaria transmission and highland epidemics.²⁵

DENGUE PREVALENCE IS EXPANDING RAPIDLY. Transmitted by *Aedes* mosquitoes, dengue is a fast growing challenge, particularly in tropical cities in developing countries. Cases have risen dramatically in the last 40 years, as unplanned urbanization with standing water in waste and other receptacles have created mosquito breeding sites, and movement of people and goods has spread both mosquito vectors and infections. For the same reasons, the distribution of dengue is also highly dependent on climate.²⁶ In the absence of changes in other determinants, studies suggest that climate change could expose an additional 2 billion people to dengue transmission by the 2080s (see Figure 3)¹⁹.



Female *Aedes aegypti* mosquito, vector of dengue and other viral diseases, and highly sensitive to climate conditions.

CDC / James Gathany

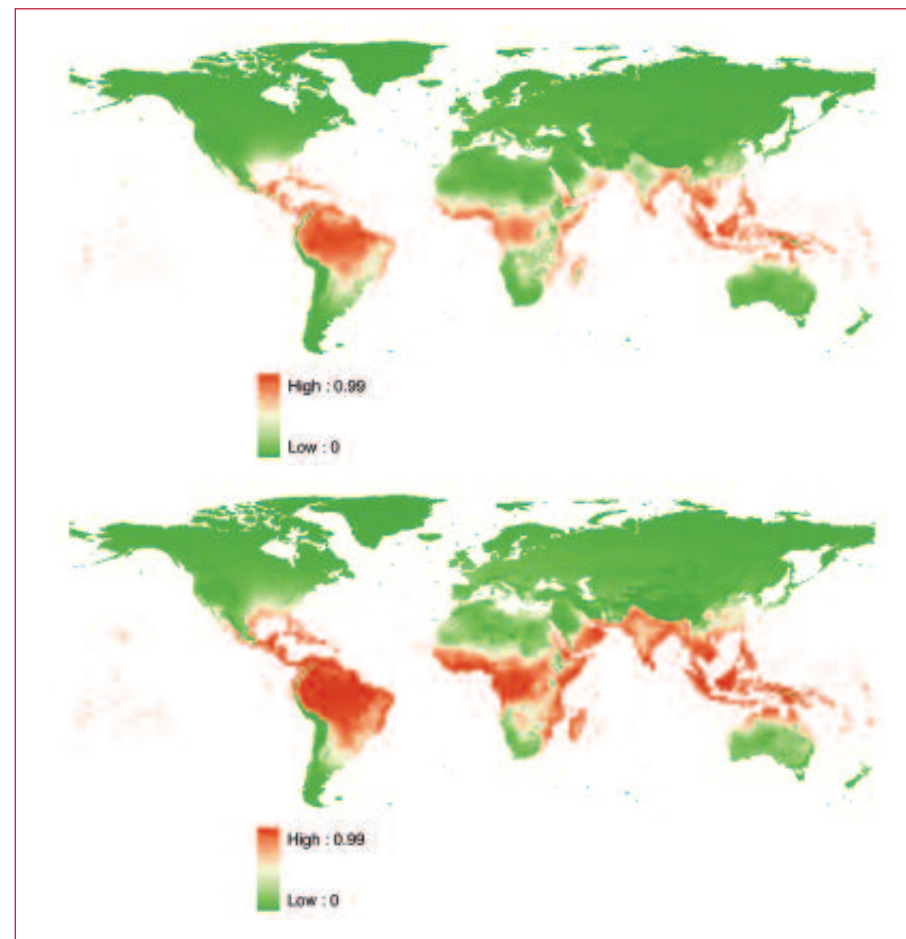
DIARRHOEA REMAINS ONE OF THE BIGGEST KILLERS OF CHILDREN. Viruses and bacteria transmitted through water and contaminated food can cause severe diarrhoea in children, often locking them into a vicious cycle of undernourishment, susceptibility to other infectious diseases, and eventually death. Higher temperatures and too much or too little water can all facilitate transmission of this disease. In countries with inadequate water and sanitation services, diarrhoea is much more common when temperatures are high. For example, rates of diarrhoeal disease in Lima, Peru, are 3–4 times higher in the summer than in the winter, increasing by 8% for every 1°C increase in temperature.²⁷ Both flooding and unusually low levels of water can also lead to water contamination and bring higher rates of illness and death from diarrhoea.²⁸ Warming and greater variability in precipitation threaten to increase the burden of this disease.

MANY OTHER DISEASES WILL ALSO BE AFFECTED. Any disease caused, transmitted or harboured by insects, snails and other cold-blooded animals can be affected by a changing climate. For example, climate change is projected to widen significantly the area of China where schistosomiasis transmission occurs.²⁹ Together, vector-borne diseases kill over 1.1 million people and cause the loss of 49 million years of healthy life, every year.¹⁷ Effects on infectious disease will not be restricted to developing tropical regions. For example, climate change is also expected to change distributions of diseases such as Lyme disease and tick-borne encephalitis, and to increase rates of *Salmonella* and other foodborne infections in Europe³⁰ and North America.³¹

NEW AND UNFAMILIAR INFECTIONS STRAIN HEALTH SERVICES AND ECONOMIES. When infectious diseases appear in new locations, where people do not have immunity and health services may not have experience in controlling or treating infections, the effects can be dramatic. When an outbreak of mosquito-borne Chikungunya disease occurred in Réunion in 2005–2006, it affected 1 in 10 of the population and decreased tourism, the island's main economic sector.

Figure 3. Changing patterns of infectious disease: the example of dengue.

Distribution of dengue in 1990 (upper graph) and projected expanded distribution in the warmer, wetter and more humid conditions expected in the 2080s (lower graph), assuming no change in non-climatic determinants of dengue distribution. The colour code shows the predicted probability of dengue transmission occurring within each of the locations.



Source: based on data from Hales et al., 2002.¹⁹

5. Long-term stresses: water shortages, malnutrition, displacement and conflict

In the long run, the greatest health risks may be not from natural disasters or disease epidemics, but from the slow build-up of pressures on natural, economic and social systems that sustain health. These are already under stress, particularly in the developing world.

MOUNTING WATER STRESS FOSTERS A RANGE OF LONG-TERM PUBLIC HEALTH CHALLENGES. Climate change is projected to bring changing rainfall patterns, increased temperatures and evaporation, and salinization of water sources through rising sea levels. In addition, over the course of the century, water supplies stored in glaciers and snow cover are projected to decline. This will reduce water availability to populations supplied by meltwater from major mountain ranges, more than one sixth of the global population. In many regions, the effects of climate change come on top of pre-existing water stress and mounting pressures of population growth, as well as extraction for irrigation and contamination from agriculture and industry.¹³

LACK OF ACCESS TO CLEAN WATER SUPPLY AND SANITATION, ALONG WITH POOR HYGIENE, IS ALREADY THE MAIN CONTRIBUTOR TO THE BURDEN OF DIARRHOEAL DISEASE.⁴ Decreasing and more erratic water supplies will only add to this burden. Water stress also necessitates the use of new water sources, including recycled wastewater for agriculture. Unless properly managed, the use of recycled wastewater can facilitate exposure to microbial contaminants and chemicals, including pesticides and fertilizers.³²

PRESSURES ON AGRICULTURE THREATEN TO INCREASE THE BURDEN OF MALNUTRITION. Undernutrition and related disease is currently the greatest contributor to the global burden of disease, killing over 3.5 million people per year, mostly children in developing countries.¹⁴ It is projected that climate change will boost agricultural production in the high latitudes of developed countries, but cause decreases in many tropical

developing regions. There is particular concern for sub-Saharan Africa, where people are most reliant on subsistence and rain-fed agriculture and have least money to buy imported food. Tens of millions more people are projected to become at risk of food insecurity and the health consequences of malnutrition.¹³

POPULATION DISPLACEMENT COMPROMISES HEALTH AND DAMAGES LIVES. By destroying ecological and agricultural systems and by flooding communities, climate change can eventually force people to abandon where they live in order to seek new homes and livelihoods. Forced displacement is associated with a range of health issues, including social isolation and mental disorders and, in many cases, reduced socioeconomic status and associated health problems. The recent record-breaking drought in Australia caused many rural families to abandon their farms and move to cities, with a range of negative social and health effects. When migration crosses ethnic and/or national boundaries, such as forced migration from low-lying, small island states, the social transition is more difficult and the associated health effects are likely to be more severe.

COMPETITION OVER DWINDLING OR DEGRADED NATURAL RESOURCES CAN INCREASE THE RISKS OF CONFLICT AND WAR. Although most conflicts are not directly related to natural resources, stresses on natural ecosystem services can lead to competition between population groups over, for example, freshwater supplies or fertile agricultural land. Combined with factors such as poor governance and ethnic rivalries, such competition can inflame tensions into conflict.³³



Oliver A. Sathornas / Norwegian Red Cross

Iridimi refugee camp in Chad: more frequent and intense drought can cause food shortages, and potentially population displacement and increasing tension and conflict between communities.

WHO IS AT RISK?

6. Vulnerable regions: exposed populations

All regions of the world will be affected by a changing climate, but the resulting health risks to human populations vary greatly, depending on where and how people live. People living in small island developing states and other coastal regions, megacities and mountainous and polar regions are all particularly vulnerable in different ways.¹³

SMALL ISLAND DEVELOPING STATES AND OTHER LOW-LYING REGIONS ARE IN THE FRONT LINE. Populations in these countries are vulnerable to death and injury and destruction of their public health infrastructure from increasingly severe tropical storms, as well as salinization of water resources and agricultural land from sea level rise.³⁴ Many of these nations struggle to supply adequate fresh water for basic sanitation and hygiene, particularly to outlying islands and other isolated areas where populations suffer elevated rates of diarrhoea and nutritional deficiencies during droughts, floods and high temperatures.²⁸

URBAN POPULATIONS, PARTICULARLY THOSE OF TROPICAL MEGACITIES, ARE EXPOSED TO A COMBINATION OF HEALTH RISKS SUCH AS HEATWAVES, FLOODS, INFECTIOUS DISEASES AND AIR POLLUTION. Rising global temperatures combine with the urban heat island effect, and can raise temperatures by 5–12° C, heightening hazards from heatwaves.^{35,36} Extensive coverage with impervious surfaces, along with inadequate drainage and precarious housing, increase the risks and the health impacts of flash floods. High population densities, inadequate coverage of clean water, sanitation and waste disposal services raise vulnerability to climate-sensitive infectious diseases such as diarrhoea and dengue. Many cities also have high levels of air pollution, almost all of which results from burning of fossil fuels.³⁷

MOUNTAIN POPULATIONS ARE AT INCREASED RISK OF WATER INSECURITY, FLOODS AND LANDSLIDES, AND INFECTIOUS DISEASE. Climate change at high altitudes can cause a range of health challenges.³⁸ The widespread retreat of glaciers threatens to deprive mountain and downstream populations of reliable summer fresh water for household use and for agriculture, from China to Peru. Swelling of the lakes that form at the bottom of glaciers increases the risks of glacier lake outburst floods, which occur suddenly and can cause injury, death and destruction in downstream communities. Furthermore, higher temperatures are intensifying the risks of transmission of vector-borne diseases, such as malaria, among high-altitude populations that lack immunity against such diseases.²⁵

THE HEALTH OF INDIGENOUS PEOPLE IN POLAR REGIONS MAY BE PARTICULARLY AFFECTED BY CHANGES IN TEMPERATURE, FOOD SOURCES AND LIVELIHOODS. Rising winter temperatures in Arctic regions are expected to reduce excess winter mortality and cold-related injuries.³⁹ However, the traditional diet of circumpolar residents is likely to be impacted by melting snow and ice, affecting animal distributions and accessibility for hunting. Wildlife and waterborne and vector-borne diseases are expected to have a wider seasonal and geographical distribution.⁴⁰ Perhaps most importantly, changes in the physical environment will make traditional ways of life impossible, forcing changes of behaviour and means of supporting livelihoods, with associated effects on mental health and community cohesion.



Laurent Weyl / ARGOS



WHO / Chris de Bode



Guillaume Collange / ARGOS



WHO / Bernd Neumann

Clockwise from top left: coastal flooding in Tuvalu, infectious disease risks in urban settings in Sierra Leone, disruption of livelihoods in Scandinavia and Nepal.

7. Children: life-long exposure to health risks from climate change

Children, particularly in poor countries, have made the least contribution to the greenhouse gases that are causing climate change, yet they are among the most vulnerable to the resulting health risks and will be exposed longer to the health consequences of a degraded natural environment.

CLIMATE-SENSITIVE DISEASES ALREADY PLACE AN ENORMOUS BURDEN ON CHILD HEALTH. The most important climate-sensitive diseases are those of poor children: 90% of the burden of malaria and diarrhoea, and almost all of the burden of diseases associated with undernutrition, are borne by children aged 5 years or less, mostly in developing countries.¹⁷

THESE MAJOR DISEASES OF CHILDREN ARE HIGHLY SENSITIVE TO VARIATIONS IN TEMPERATURE AND PRECIPITATION. The problems of undernutrition and associated diseases are most common among populations that are either directly dependent on rain-fed subsistence agriculture or who have low incomes and therefore high sensitivity to increases in food prices when harvests are diminished by floods and drought. The distribution of malaria in time and location is influenced to a large extent by temperature, humidity and rainfall. Childhood diarrhoea in developing countries has been shown to increase significantly with higher temperatures, or at times of low water availability (making hygiene more difficult) and flooding (contaminating freshwater sources).

CLIMATE CHANGE THREATENS TO INTENSIFY THESE BURDENS FURTHER. Progress towards all of the health-related Millennium Development Goals, from reduction of childhood mortality to eradication of extreme poverty and hunger, should reduce the vulnerability of children. However, progress is slower than hoped, and climate change threatens to create further setbacks. For example, unless adaptation measures are taken, climate change is projected to increase the percentage of the population of Mali at risk of hunger from 34% to 64–72% by the 2050s.⁴¹ Several studies project that rising temperatures and changing rainfall patterns are likely to increase significantly the population at risk of malaria in Africa¹⁸ and the number of months of exposure to transmission.⁴² The resulting disease burden can be expected to affect mainly children.

CHILDREN HAVE LITTLE IMPACT ON MANY ADAPTATION AND MITIGATION DECISIONS. Children have heightened vulnerability to health risks from climate change: both because they suffer disproportionately from climate-sensitive disease and because they will be exposed longer to the accumulating damage that climate change is inflicting on the natural environment. They bear little or no responsibility, however, for past and present emissions of the greenhouse gases that are now causing climate change. The responsibility to protect and enhance the health of children therefore lies with adults, from parents to community, business and national leaders who take decisions on climate change mitigation and adaptation.



S.Channanirith - UNEP/Still Pictures

Thailand: some of the most severe risks, both now and in the future, are for children.

8. The most vulnerable: they support the greatest health burdens

Natural disasters, such as the European heatwave of 2003 and Hurricane Katrina in the USA in 2005, show that, even in the most developed countries, health is vulnerable to weather and climate. The risks are particularly high, however, for the poorest populations, who already suffer from high burdens of climate-sensitive disease and lack effective public health systems to protect them from the increased risks associated with climate change.

THE BURDEN OF CLIMATE-SENSITIVE DISEASES IS GREATEST FOR THE POOREST POPULATIONS. For example, the per capita mortality rate from vector-borne diseases is almost 300 times greater in developing nations than in developed regions.¹⁷ This is because vector-borne diseases are more common in tropical climates of many developing countries, and also because of low levels of socioeconomic development and coverage of health services in these areas.

CLIMATE-RELATED HEALTH RISKS ARE OFTEN GREATER FOR POOR INDIVIDUALS WITHIN ANY POPULATION. In developing countries, individuals without adequate shelter or access to health and other critical services are more vulnerable to a range of risks related to weather and climate, from flooding to infectious diseases. For example, diseases transmitted by water, soil and vectors, such as schistosomiasis,⁴³ hookworm⁴⁴ and filariasis,⁴⁵ are often many times more common among people with the lowest socioeconomic status in any one location. The same pattern occurs in rich countries: in the wake of Hurricane Katrina in the USA, lower-income groups were most affected and low-income schools had double the average risk of being flooded.⁴⁶



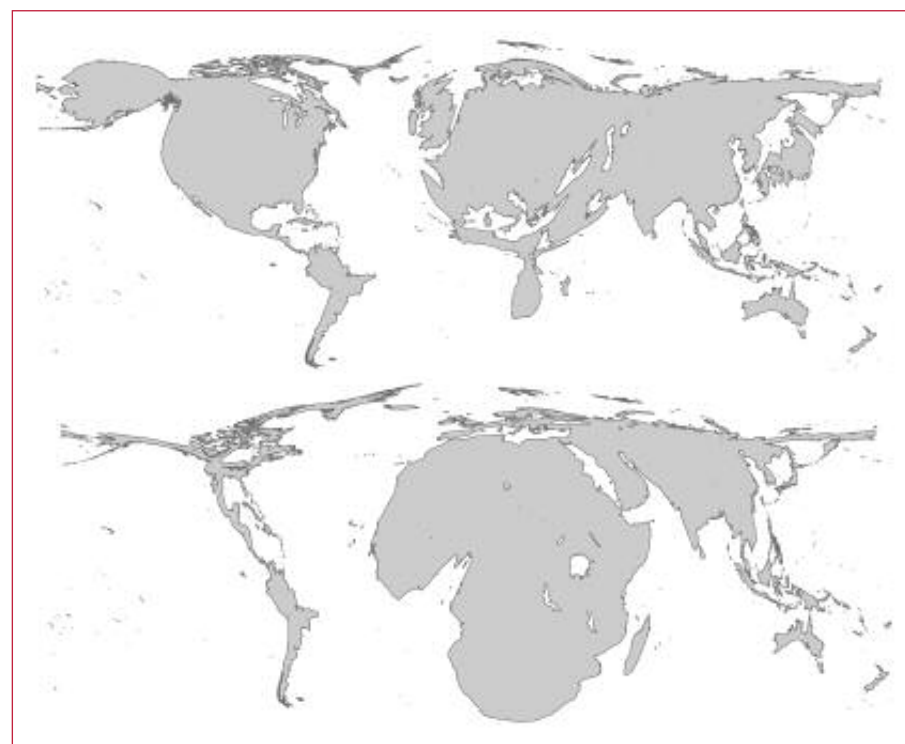
Northern Kenya: the poorest populations are most vulnerable to drought and other consequences of climate change.

WOMEN AND CHILDREN IN DEVELOPING COUNTRIES ARE PARTICULARLY VULNERABLE TO DEATH AND ILLNESS FOLLOWING NATURAL DISASTERS. In the 1991 cyclone disasters that killed 140 000 people in Bangladesh, death rates among women were almost four times greater than those among men: rates among children under 10 years of age were more than six times greater than those of adult men.⁴⁷ Natural disasters can also result in increased suffering from domestic violence and post-traumatic stress disorders in women,^{48,49} who are also often called upon to play a leading role in disaster recovery and in rebuilding shattered communities.

CLIMATE CHANGE AND ASSOCIATED DEVELOPMENT PATTERNS THREATEN TO WIDEN EXISTING HEALTH INEQUALITIES BETWEEN AND WITHIN POPULATIONS. A WHO assessment of the burden of disease caused by climate change suggested that the modest warming that has occurred since the 1970s was already causing over 150 000 excess deaths annually by the year 2000. The estimated per capita impacts were many times greater in regions that already had the greatest disease burden.^{4,50} Health benefits of climate change – mainly decreased mortality from cold winters – are less strongly supported by evidence; to the extent that they do occur, they are expected to benefit mainly populations in high-latitude developed countries.^{5,50} The disproportion of populations that have contributed the least to climate change and are the most vulnerable to health risks is graphically presented in Figure 4. The ongoing process of climate change is likely to widen the existing health disparities between the richest and the poorest populations.

Figure 4. Poorer countries contribute little to greenhouse gas emissions, but are most vulnerable to health impacts.

The top image shows countries scaled by total emissions of CO₂ to 2002; the bottom image shows countries scaled by WHO regional estimates of *per capita* mortality from climate change in 2000⁵⁰.



Source: map projections by Patz et al., 2007.⁵¹



9. All of us: our shared health security

Globalization has brought benefits of efficient transport and trade, with rapid flows of people, goods and services; but in an increasingly interconnected world, some health risks can quickly spread from one location to another. Now, more than ever, protecting and promoting the health of all populations is a global public good.

CLIMATE CHANGE MAKES PROTECTING GLOBAL PUBLIC HEALTH SECURITY EVEN MORE DIFFICULT. The underlying problems of public health security are long-standing: inadequate investment in public health services and global disease surveillance and control, and failure to manage environmental risks to health.⁵² Climate change brings a new dimension to this problem, exacerbating the worldwide risks of sudden shocks such as heatwaves, floods and disease epidemics, as well as accelerating long-term stresses such as the availability of fresh water. All of these changes can have impacts far beyond the locations in which they originally occur.

INFECTIOUS DISEASES CAN NOW SPREAD RAPIDLY THROUGHOUT THE WORLD. The last decades of the 20th century saw an unprecedented rate of emergence of new infectious diseases.⁵³ They also saw the re-emergence and regional spread of many existing climate-sensitive infections: such as cholera and Rift Valley fever in Africa, and dengue in Latin America and South Asia.⁵⁴ These outbreaks can cause major economic losses. For example, a cholera outbreak in Peru in 1991 cost approximately US\$ 770 million, and the 1994 plague outbreak in India US\$ 1.7 billion.⁵⁵ A warming and more variable climate, coupled with globalization, hastens the speed with which these diseases change in distribution and move across international borders. Unusual weather patterns may also contribute to the emergence of new diseases, such as hantavirus pul-

monary disease in the southwestern United States and Nipah virus infection in Asia, especially in areas where human impacts on the environment have been increasing most rapidly.⁵³

COMPETITION OVER SCARCER NATURAL RESOURCES, AND WIDENING INEQUALITIES, CAN FUEL REGIONAL TENSIONS. In northern Darfur, Sudan, precipitation has fallen by a third in the past 80 years. The resulting desertification, along with other environmental pressures, has added to the stress on traditional agricultural and pastoral livelihoods. By early 2008, fighting in the region had cost between 200 000 and 500 000 lives and displaced over 2.5 million people, many of whom are living in refugee camps in precarious health conditions. The conflict has resulted in deployment of troops from other African countries and has spilled over into neighbouring Chad. Ongoing climate change, particularly declining and more variable rainfall, is expected to reduce yields of staple crops by up to 70% in the most vulnerable areas.³³

THE RISKS TO HUMAN SECURITY FROM CLIMATE CHANGE AND FOSSIL FUEL DEPENDENCE ARE NOW BEING RECOGNIZED. Surveys have shown that many populations, including those in Australia, China and Italy, place climate change high on lists of threats to their security and well-being. Military leaders and researchers have stressed that climate change, national security and energy dependence are closely related, with dependence on foreign oil heightening vulnerability to hostile attacks and involvement in foreign conflicts.^{56,57} This concern is now reflected at the highest level; in 2007, climate change was debated for the first time at the United Nations Security Council, as well as in a special session of the United Nations General Assembly.



WHO / Benno Neukann

Bangladesh: sheltering from heavy rainfall. Infectious diseases can now spread rapidly to any part of the world – calling for health protection for all.

WHAT NEEDS TO BE DONE?

10. Putting health at the heart of the climate change agenda

Climate change can no longer be considered simply as an environmental or a developmental issue. It will affect the health and well-being of all populations, with impacts escalating into the foreseeable future. A greater understanding of the health implications of climate change – and related development choices – can lead to improved policies and more active public engagement.

HUMAN HEALTH NEEDS TO BE PLACED AT THE CENTRE OF ENVIRONMENT AND DEVELOPMENT DECISIONS. There is a growing appreciation that the natural environment should be valued not just for its own sake, but for the “goods and services” that it provides to support human societies; and that economic development is not an end in itself, but a means to improving human lives.⁵⁸ It is essential that the same reasoning be applied to climate change. The ultimate aim of mitigation and adaptation, and related development decisions, should be the protection and improvement of human well-being.

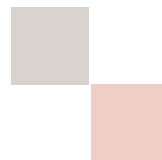
THIS REPORT DOCUMENTS THE RANGE OF RISKS THAT CLIMATE CHANGE POSES TO HUMAN HEALTH. The extent to which these risks translate into increased disease burdens, will depend on the efforts that we make to protect health through adaptation, and to reduce our impacts on the global climate.

ECONOMIC GROWTH IN THE POOREST COUNTRIES IS CRITICAL TO REDUCING VULNERABILITY – BUT PUBLIC HEALTH MEASURES ARE ALSO REQUIRED. There is abundant evidence that countries with a higher level of economic development tend to have better health, including reduced vulnerability to many climate-sensitive diseases. Continued economic growth in the poorest populations is therefore vital to protecting health

from climate change. However, economic growth is itself a risk for climate change⁵⁹ and, depending on the development path that is followed, it can increase environmental risks to health and leave large sections of the population vulnerable. Greater attention to public health planning is necessary, particularly to safeguard the health of the most vulnerable population groups, which is, in turn, a contribution to sustained economic development.⁶⁰

PROTECTION FROM CLIMATE CHANGE IS PART OF A BASIC, PREVENTIVE APPROACH TO PUBLIC HEALTH, NOT A SEPARATE OR COMPETING DEMAND. Strong actions on adaptation and mitigation are necessary to protect health from climate change. Many of the most important actions are public health interventions of proven effectiveness, from controlling vector-borne disease, to providing clean water and sanitation and reducing reliance on energy sources that pollute the environment and harm health. All would improve health now, as well as reducing vulnerability to climate change in the future.

MEASURES THAT BOTH PROMOTE HEALTH AND CUT GREENHOUSE GAS EMISSIONS ARE LIKELY TO HAVE WIDESPREAD SUPPORT. Many of the measures that would reduce greenhouse gas emissions, such as shifting to cleaner energy sources, could bring important health “co-benefits” to communities and individuals, for example through reduced air pollution. These local and immediate benefits can offset a large part of the costs of mitigation and provide a strong motivation for action.





Hélène David / ARGOS

Shifmaref, Alaska, USA: the human face of climate change. Sea-level rise, storms and coastal erosion are not just an environmental issue – they affect the lives and well-being of people throughout the world.

11. Strengthening public health systems

The global public health community has a wealth of experience in protecting people from climate-sensitive hazards. Many of the necessary preventive actions to deal with the additional risks of climate change are already clear. Widening the coverage of proven, effective health interventions will be critical to the global effort to adapt to climate change.

STRENGTHENING OF PUBLIC HEALTH SYSTEMS IS ALREADY NECESSARY; CLIMATE CHANGE MAKES THIS NEED EVEN MORE CRITICAL. Today's shortfalls in providing basic public health services leave much of the global population exposed to climate-related health risks. There is a need for additional investment to strengthen key functions and for forward planning to address the new challenges posed by climate change.

ENHANCED CAPACITY TO ADDRESS PUBLIC HEALTH EMERGENCIES SAVES LIVES AND PROTECTS COMMUNITIES. Acute shocks such as natural disasters and disease epidemics can overload the capacities of health systems in even the most developed nations. The number of disasters reported and the numbers of people affected have risen in recent decades. Conversely, the number of people killed has fallen, as societies and individuals have become more able to protect themselves. Further reinforcing disaster risk reduction, early warning, and health action in emergencies can help to ensure that people are better protected from the increasing hazards of extreme weather and help communities recover faster following a disaster.⁶¹

STRENGTHENED SURVEILLANCE AND CONTROL OF INFECTIOUS DISEASE CAN PROTECT HEALTH FROM LOCAL TO GLOBAL SCALES. Effective disease surveillance and control become even more important under conditions of rapid environmental change and movement of people, disease vectors and infections. Rapid and accurate disease notification, in compliance with the International Health Regulations,⁶² is the essential basis for planning disease control. Approaches such as Integrated Vector

Actions to improve our health and protect our climate: the health sector leads by example

- Assess and plan for health challenges arising from climate change. Consider how the changing climate is likely to affect health risks in the populations that you are responsible for, and what changes you may need to make in your own work, such as responding to changes in seasonal patterns of disease transmission.
- Provide guidance on the health implications of climate change and development policies. Ensure that health is represented in national adaptation and mitigation climate change plans, and advise on both the positive and negative health effects of key decisions, such as on energy production, transport and water resources.
- Work to reduce the environmental impact of your institutions, working practices and lifestyles. Good practice in managing energy use, transport and procurement can cut costs and improve health service provision.

Management make the best use of proven interventions, such as bednets, insecticide spraying and environmental management, to control malaria, dengue and other vector-borne tropical diseases that may otherwise expand through climate change.⁶³ Improving access to primary health care ensures faster treatment for patients, alleviating suffering and containing the risks of disease spread.

IMPROVING THE ENVIRONMENTAL AND SOCIAL DETERMINANTS OF HEALTH IS CRITICAL TO PROTECTING POPULATIONS FROM CLIMATE CHANGE. Addressing known environmental risk factors could greatly improve health, while supporting sustainable development. Improving



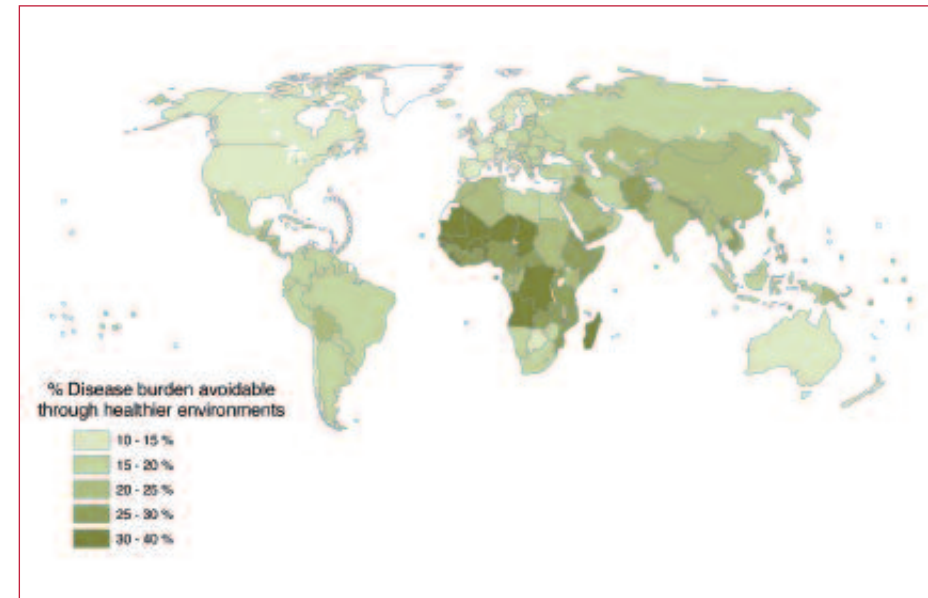
environmental conditions could prevent up to a quarter of the global burden of disease, rising to a third in the poorest countries⁶⁴ (see Figure 5). For example, scaling up water and sanitation services and household disinfection would immediately reduce diarrhoea and, at the same time, lessen the health impacts of decreasing and more variable water supplies. The benefits of such interventions are already several times greater than the costs,⁶⁴ and the threat of climate change makes these preventive health measures an even wiser investment. Improving social welfare, particularly educating and empowering women in developing countries, is a fundamental requirement for improving health. It is also essential to strengthening community resilience to climate change.



Indonesia: strengthening public health interventions, such as rapid surveillance and control of infectious disease, is essential to meeting the challenge of climate change.

THE RISKS OF CLIMATE CHANGE CALL FOR MORE EQUITABLE ACCESS TO PUBLIC HEALTH SERVICES. The health of the poorest and most disadvantaged people is particularly threatened by climate-sensitive diseases, and by climate change. Greater emphasis will need to be placed on protecting the health of particularly vulnerable groups, in order to ensure that this emerging risk does not further widen the gaps in health outcomes between the most and the least privileged.

Figure 5. Estimated proportion of the total burden of disease that could be prevented through proven interventions to reduce environmental health risks.



Source: based on data from Pruss-Üstün & Corvalán, 2006⁶⁴, WHO⁶⁵



Acknowledgements:

Technical input and production: Diarmid Campbell-Lendrum, Roberto Bertollini, Maria Neira, Emilie Ferreira, Nada Osseiran and Colin Mathers (WHO).

Contribution of data: Simon Hales, Debarati Guha-Sapir, Jonathan Patz, Holly Gibbs and Aaron Ruesch.

Editing: Barbara Campanini

Cover design: Saatchi and Saatchi

Layout: ALIASgraphix

REFERENCES

1. *Climate change 2007. The physical science basis: summary for policymakers*. Geneva, Intergovernmental Panel on Climate Change, 2007 (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change).
2. United Kingdom Government Met Office. *HadCRUT3 annual time series*, Hadley Research Centre, 2008 (<http://hadobs.metoffice.com/hadcrut3/diagnostics/global/nh%2Bsh/index.html>).
3. *The state of food insecurity around the world. Eradicating hunger – Key to achieving the Millennium Development Goals*. Rome, Food and Agriculture Organization of the United Nations, 2005:40 (<http://www.fao.org/docrep/008/a0200e/a0200e00.htm>).
4. *The world health report 2002 – Reducing risks, promoting healthy life*. Geneva, World Health Organization, 2002.
5. Confalonieri U et al. Human health. In: Parry ML et al., eds. *Climate change 2007. Impacts, adaptation and vulnerability*. Cambridge, Cambridge University Press, 2007, 391–431 (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change).
6. Robine JM et al. Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendues Biologie*, 2008, 331:171–78.
7. Beniston M, Diaz HF. The 2003 heat wave as an example of summers in a greenhouse climate? Observations and climate model simulations for Basel, Switzerland. *Global and Planetary Change*, 2004, 44:73–81.
8. Cohen A et al. Urban air pollution. In: Ezzati M et al., eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva, World Health Organization, 2004:1353–1433.
9. Jacobson MZ. On the causal link between carbon dioxide and air pollution mortality. *Geophysical Research Letters*, 2008, 35(L03809, doi:10.1029/2007GL031101).
10. Arnell NW. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change – Human and Policy Dimensions*, 2004, 14:31–52.
11. Burke EJ, Brown SJ, Christidis N. Modeling the recent evolution of global drought and projections for the twenty-first century with the Hadley Centre climate model. *Journal of Hydrometeorology*, 2006, 7:1113–1125.
12. Prüss-Üstün A et al. Unsafe water, sanitation and hygiene. In: Ezzati M et al., eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva, World Health Organization, 2004:1353–1433.
13. *Climate change 2007. Impacts, adaptation and vulnerability*. Geneva, Intergovernmental Panel on Climate Change, 2007 (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change).
14. Black RE et al. Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet*, 2008,371:243–260.
15. Nicholls RJ et al. Coastal systems and low-lying areas. In: Parry ML et al. eds. *Climate change 2007. Impacts, adaptation and vulnerability*. Cambridge, Cambridge University Press, 2007:315–356 (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change).
16. Hales S, Edwards S, Kovats R. Impacts on health of climate extremes. In: McMichael AJ et al., eds. *Climate change and health: risks and responses*. Geneva, World Health Organization, 2003.
17. *Burden of disease statistics*. Geneva, World Health Organization, 2006 (<http://www.who.int/entity/healthinfo/statistics/gbdwhoregionmortality.xls>).
18. Hay SI et al. *Foresight on population at malaria risk in Africa: 2005, 2015 and 2030*. London, Office of Science and Innovation, Foresight Project, 2006:40 (Scenario review paper prepared for the Detection and Identification of Infectious Diseases Project (DIID); http://www.foresight.gov.uk/Detection_and_Identification_of_Infectious_Diseases/Reports_and_Publications/Final_Reports/T/T8_2.pdf).
19. Hales S et al. Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet*, 2002, 360:830–834.
20. John M. *U.N. aid chief worried by food inflation, weather*. Reuters, 29 January 2008.
21. Schar C et al. The role of increasing temperature variability in European summer heatwaves. *Nature*, 2004, 427:332–336.
22. Palmer TN, Ralsanen J. Quantifying the risk of extreme seasonal precipitation events in a changing climate. *Nature*, 2002, 415:512–514.
23. Knutson TR, Tuleya RE. Impact of CO₂-induced warming on simulated hurricane intensity and precipitation: sensitivity to the choice of climate model and convective parameterization. *Journal of Climate*, 2004, 17: 3477-3495.
24. EM-DAT. The OFDA/CRED International Disaster Database. Brussels, Université Catholique de Louvain, 2008 (www.cred.be/emdat).
25. Pascual M et al. Malaria resurgence in the East African highlands: temperature trends revisited. *Proceedings of the National Academy of Sciences of the USA*, 2006,103:5829–5834.
26. Rogers DJ et al. The global distribution of yellow fever and dengue. *Adv Parasitology*, 2006, 62:181–220.
27. Checkley W et al. Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet*, 2000, 355:442–450.

- 
28. Singh RB et al. The influence of climate variation and change on diarrheal disease in the Pacific Islands. *Environmental Health Perspectives*, 2001, 109:155–159.
 29. Zhou XN et al. Potential impact of climate change on schistosomiasis transmission in China. *American Journal of Tropical Medicine and Hygiene*, 2008, 78:188–194.
 30. Menne B, Ebi K. *Climate change and adaptation strategies for human health*. Darmstadt, Steinkopff Verlag, 2005.
 31. Ebi KL et al. Climate change and human health impacts in the United States: an update on the results of the US national assessment. *Environmental Health Perspectives*, 2006, 114:1318–1324.
 32. *WHO guidelines for the safe use of wastewater, excreta and greywater*, 3rd ed. Geneva, World Health Organization, 2006.
 33. *Sudan post-conflict environmental assessment*. Nairobi, United Nations Environment Programme, 2007 (http://postconflict.unep.ch/publications/sudan/00_fwd.pdf).
 34. *Climate variability and change and their health effects in small island states: information for adaptation planning in the health sector*. Geneva, World Health Organization, 2006 (<http://www.who.int/globalchange/climate/climatevariab/en/index.html>).
 35. Aniello C et al. Mapping micro-urban heat islands using Landsat TM and a GIS. *Computers & Geosciences*, 1995, 21:965–969.
 36. Patz JA et al. Impact of regional climate change on human health. *Nature*, 2005, 438:310–317.
 37. Campbell-Lendrum D, Corvalan C. Climate change and developing-country cities: implications for environmental health and equity. *Journal of Urban Health*, 2007, 84:i86–97.
 38. *Human health impacts of climate variability and climate change in the Hindu Kush-Himalaya region. Report of a regional workshop, Mukteshwar, India*. New Delhi, World Health Organization Regional Office for South-East Asia, 2006.
 39. Nayha S. Environmental temperature and mortality. *International Journal of Circumpolar Health*, 2005, 64:451–458.
 40. Parkinson AJ, Butler JC. Potential impacts of climate change on infectious diseases in the Arctic. *International Journal of Circumpolar Health*, 2005, 64:478–486.
 41. Butt TA et al. The economic and food security implications of climate change in Mali. *Climatic Change*, 2005, 68:355–378.
 42. Tanser FC, Sharp B, le Sueur D. Potential effect of climate change on malaria transmission in Africa. *Lancet*, 2003, 362:1792–1798.
 43. Ximenes R et al. Socioeconomic determinants of schistosomiasis in an urban area in the Northeast of Brazil. *Revista Panamericana de Salud Pública*, 2003, 14:409–421.
 44. Hotez P. Hookworm and poverty. *Annals of the New York Academy of Sciences*, 2008:1–7.
 45. Ottesen EA et al. Strategies and tools for the control/elimination of lymphatic filariasis. *Bulletin of the World Health Organization*, 1997, 75:491–503.
 46. Guidry VT, Margolis LH. Unequal respiratory health risk: Using GIS to explore hurricane related flooding of schools in Eastern North Carolina. *Environmental Research*, 2005, 98:383–389.
 47. Bern C et al. Risk factors for mortality in the Bangladesh cyclone of 1991. *Bulletin of the World Health Organization*, 1993, 71:73–78.
 48. Ariyabandu M, Wickramasinghe M. *Gender dimensions in disaster management: a guide for South Asia*. Colombo, ITGD South Asia, 2003.
 49. Galea S, Nandi A, Vlahov D. The epidemiology of post-traumatic stress disorder after disasters. *Epidemiological Review*, 2005, 27:78–91.
 50. McMichael A, et al. Climate change. In: Ezzati M et al., eds. *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors*. Geneva, World Health Organization, 2004.
 51. Patz J et al. Climate change and global health: quantifying a growing ethical crisis. *Ecobhealth*, 2007, 4:397–405.
 52. *The world health report 2007 – A safer future: global public health in the 21st century*. Geneva, World Health Organization, 2007.
 53. Jones KE et al. Global trends in emerging infectious diseases. *Nature*, 2008, 45:990–994.
 54. *Invest in health, build a safer future*. Geneva, World Health Organization, 2007 (World Health Day 2007 Issues paper).
 55. Rockenschaub G, ed. *Towards health security: a discussion paper on recent health crises in the WHO European Region*. Copenhagen, World Health Organization Regional Office for Europe, 2007 (<http://www.euro.who.int/healthy-cities>).
 56. Campbell KM et al. *The age of consequences: the foreign policy and national security implications of global climate change*. Washington, DC, Center for Strategic and International Studies, 2008 (http://www.csis.org/media/csis/pubs/071105_ageofconsequences.pdf).
 57. CNA Corporation. *National security and the threat of climate change*. Alexandria, VA, 2007 (<http://securityandclimate.cna.org/report/>).
 58. *Millennium ecosystem assessment. Ecosystems and human well-being: health synthesis*. Geneva, World Health Organization, 2005.
 59. Stern N. *Stern review on the economics of climate change*. London, Treasury, 2006.

60. *Macroeconomics and health: investing in health for economic development. Report of the Commission on Macroeconomics and Health.* Geneva, World Health Organization, 2001 (http://www3.who.int/whosis/cmh/cmh_report/report.cfm?path=whosis,cmh,cmh_report&language=english#).
61. *Environmental health in emergencies.* Geneva, World Health Organization, 2008 (http://www.who.int/environmental_health_emergencies/en/)
62. *International health regulations.* Geneva, World Health Organization, 2007 (http://www.who.int/gb/ebwha/pdf_files/WHA58/WHA58_3-en.pdf)
63. *Global strategic framework for integrated vector management.* Geneva, World Health Organization, 2004 (http://whqlibdoc.who.int/hq/2004/WHO_CDS_CPE_PVC_2004_10.pdf).
64. Prüss-Üstün A, Corvalán C. *Preventing disease through healthy environments: towards an estimate of the environmental burden of disease.* Geneva, World Health Organization, 2006.
65. *Country profiles of environmental burden of disease.* Geneva, World Health Organization, 2008 (http://www.who.int/quantifying_ehimpacts/national/countryprofile/en/index.html).



Contact Information

World Health Organization
Avenue Appia 20
CH - 1211 Geneva 27
Switzerland
Tel +41 22 791 2111
Fax +41 22 791 3111



<http://www.who.int/world-health-day/en/>

ISBN 978 92 4 159652 7

