

Adaptation and adaptive capacity in the public health context

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Introduction

Understanding of Earth's climate systems has advanced substantially over the past decade (1). Research has provided valuable information about the potential health risks associated with climate change (2). Despite impressive progress in climate science and health impacts research many unresolved questions remain. While there are considerable uncertainties, as the knowledge base on climate change and health impacts has grown, so has interest in developing response options to reduce adverse health effects. That is, in addition to measures aimed at reducing greenhouse gases and slowing climate change, measures can be aimed at reducing adverse effects (or exploiting beneficial effects) associated with climate change. Even with reductions in greenhouse gas emissions Earth's climate is expected to continue to change so that adaptation strategies are viewed as a necessary complement to mitigation actions. Past experience with climate shows that there is substantial capacity to adapt to a range of conditions through a wide variety of adaptation measures (2).

The purpose of this chapter is to describe adaptation in the public health context. The first section defines adaptation and adaptive capacity as used in the climate change community. A discussion of the need to consider adaptation when assessing health impacts and vulnerability also is included. The next section maps adaptation concepts into the more familiar public health concepts of primary, secondary and tertiary prevention. The concept of coping ability is discussed in the third section and adaptive capacity, including the determinants of adaptive capacity, in the next. A brief description of research needs and concluding thoughts complete this chapter. Chapter 12 provides real-world examples of public health adaptations to climate and discusses policy implications.

Adaptation

Several definitions of climate-related adaptation can be found in the literature and continue to evolve (see summary in Smit et al. (3)). Many definitions focus on human actions (4, 5), some include current climate variability and extreme events (6), others are limited to adverse consequences of climate change (5, 7). The Intergovernmental Panel on Climate Change (IPCC) (2) has developed definitions of adaptation and the closely related concept of adaptive capacity as follows:

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Adaptation: adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive Capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

These definitions are comprehensive in that they are not limited to either human or natural systems: both current and future changes in climate are encompassed, and beneficial as well as adverse effects of climate change are included. In this chapter, the terms adaptation and adaptive capacity will be used as defined in IPCC (2), although greater emphasis is placed on adaptations that cope with adverse consequences of climate change. That is, the primary objective of adaptation in the public health context is to reduce disease burdens, injuries, disabilities, suffering and deaths (8).

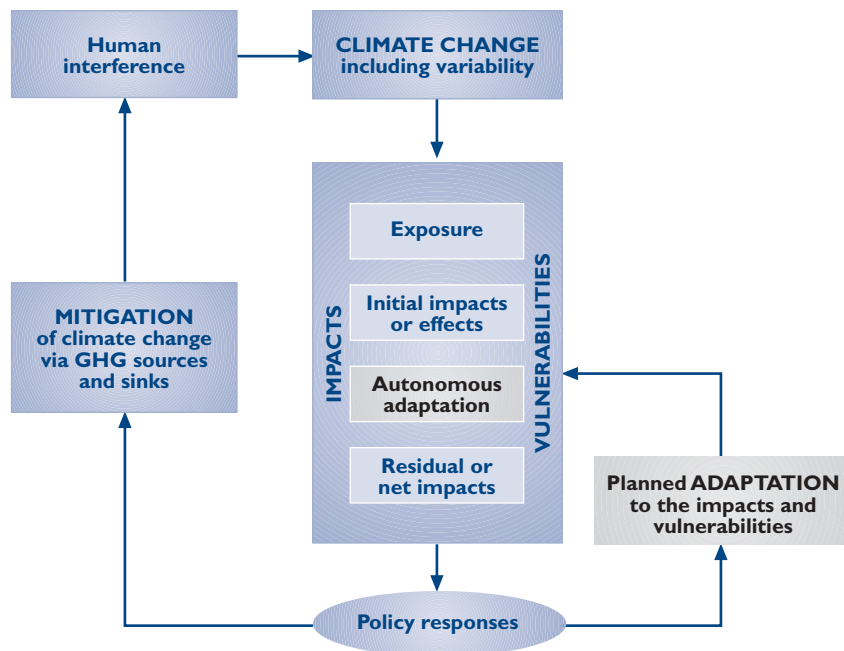
Adaptation, climate impacts, and vulnerability assessment

In order to assess health impacts of, and vulnerability to, climate change and variability it is essential to consider adaptation (2). The ultimate objective of the United Nations Framework Convention on Climate Change (9) (UNFCCC) is “to achieve stabilization of atmospheric concentrations of greenhouse gases at levels that would prevent dangerous anthropogenic (human-induced) interference with the climate system . . .”. However, the UNFCCC does not define dangerous levels, although it does refer to levels that “allow ecosystems to adapt, ensure food production is not threatened, and enable economic development to proceed in a sustainable manner” (9). As human population health also depends on these factors, it can serve as an important integrating index of effects of climate change on ecosystems, food supplies, and social-economic development (2). The extent to which the health of human populations is vulnerable or in danger depends on the direct and indirect exposures of human populations (e.g. through disturbances of ecosystems, disruptions in agriculture) to climate change effects; the populations’ sensitivity to the exposure; and the affected systems’ ability to adapt. To assess the human health risks associated with climate change, impact and vulnerability assessments must address adaptation (see Figure 11.1).

As shown in Figure 11.1, adaptation is considered both in the assessment of impacts and vulnerabilities and as a response option (2). Due to the past accumulation of greenhouse gases (atmospheric concentrations of CO₂ have increased 31% since 1750), the long lifetimes of these gases and the thermal inertia of the climate system, it is likely that global temperatures will increase and other aspects of climate continue to change regardless of the coordinated international mitigation actions undertaken (8, 10). Further, it is unlikely that autonomous actions undertaken by individuals or countries in reaction to climate health impacts will fully ameliorate all impacts (they don’t now) (2, 11). As a result, it is prudent to develop planned adaptation strategies that address future changes in climate and impacts. Article 4.1 of the UNFCCC commits parties to formulate and implement national and, where appropriate, regional programmes of “measures to facilitate adequate adaptation to climate change”.

Although climate impact and vulnerability studies consider adaptation, they rarely do more than identify potential adaptation options or model them in a simple way, relying on a number of simplifying assumptions. Research is needed

FIGURE 11.1 Climate change and adaptation. Source: reproduced from reference 2.



on the dynamics and processes of adaptation decision-making, including the roles and responsibilities of individuals, communities, nations, institutions and the private sector.

Adaptation and prevention

Many of the adaptive measures discussed in health impact and vulnerability assessments are not unique to climate change (12, 13). In fact, the IPCC identified rebuilding public health infrastructure as “the most important, cost-effective and urgently needed” adaptation strategy (2). Other measures endorsed by the IPCC include public health training programmes; more effective surveillance and emergency response systems; and sustainable prevention and control programmes. These measures are familiar to the public health community and needed regardless of whether or not climate changes: they constitute the basis of a “no-regrets” adaptation strategy.

Adaptive actions to reduce health impacts can be considered in terms of the conventional public health categories of primary, secondary, and tertiary prevention (8, 13, 14). Primary prevention refers to an intervention implemented before there is evidence of disease or injury: avoiding hazardous exposure, removing causative risk factors or protecting individuals so that exposure to the hazard is of no consequence. For example, bed nets can be supplied to populations at risk of exposure to malaria and early warning systems (e.g. extreme heat-health warnings, famine early warning) established to provide information on hazards and recommended actions to avoid or reduce risks. Primary prevention largely corresponds to anticipatory adaptation.

Secondary prevention involves intervention implemented after disease has begun, but before it is symptomatic (e.g. early detection or screening), and sub-

sequent treatment that averts full progression to disease. Examples include enhancing monitoring and surveillance; improving disaster response and recovery; and strengthening the public health system's ability to respond quickly to disease outbreaks. Secondary prevention is analogous to reactive adaptation. Finally, tertiary prevention attempts to minimize the adverse effects of an already present disease or injury (e.g. better treatment of heat stroke, improved diagnosis of vector-borne diseases). As the adverse health outcome is not prevented, tertiary prevention is inherently reactive.

Climate-related adaptation strategies should not be considered in isolation of broader public health concerns such as population growth and demographic change; poverty; public health infrastructure; sanitation, availability of health care; nutrition; dangerous personal behaviours; misuse of antibiotics; pesticide resistance; and environmental degradation (12). All of these factors (and others) will influence the vulnerability of populations and the health impacts they experience, as well as possible adaptation strategies.

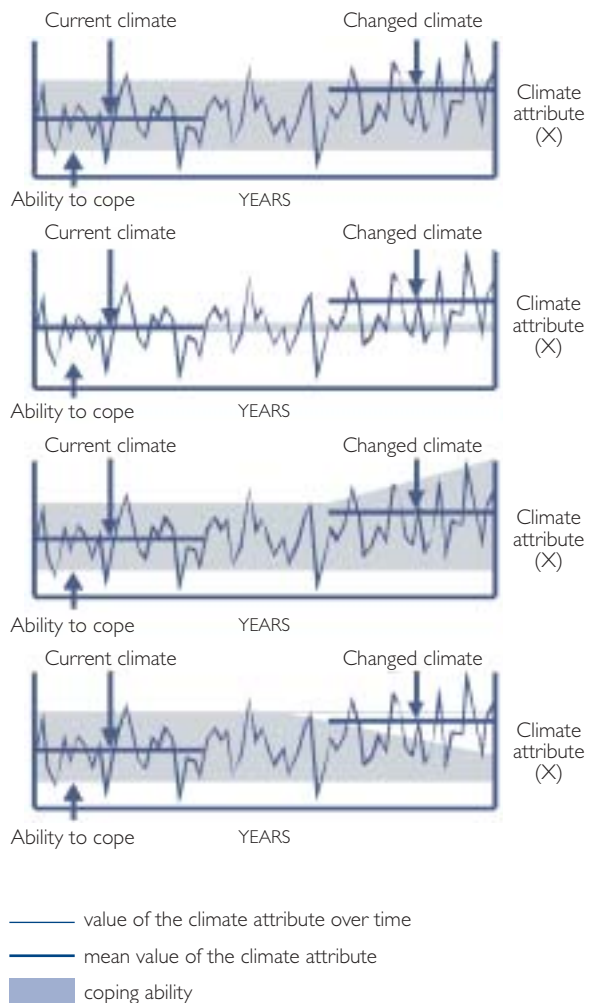
Coping with climate

Past and current climates have been, and are, variable. This variability is likely to continue with future climate change (1). In the popular literature, global climate change frequently is called 'global warming' which focuses attention on average global temperature change (a frequently cited IPCC number is average surface air temperature change, projected to warm 1.4 to 5.8°C over the next century). However, a change in climate actually occurs as changes in particular weather conditions, including extremes, in specific places. In many cases the meteorological variables of interest for public health are not averages and may not be confined to temperature alone. For example, a 2°C increase in average summer temperature in a specific urban area could result in both higher maximum temperatures and an increase (potentially large) in the number of days over some temperature threshold (say 35°C), each of which may be important for human health effects associated with heatwaves (15). In addition, changes in humidity and wind speed also may be important in terms of how people experience and are affected by these temperatures (16). Thus, adaptation to climate change necessarily includes adaptation to variability (3, 17, 18).

Given current climate variability, climate change adaptations which enhance a country's coping ability can be expected to yield both near-term benefits, as they enable countries to deal better with current variability, and the longer-term benefits of being able to deal better with future climate (19, 20, 21). Such no-regrets adaptations are likely to be especially important for less developed countries as they result in immediate benefits and are a useful first step in strengthening capacity to deal with future changes (22).

Many social and economic systems have evolved to accommodate the normal climate and some variation around this norm (see Figure 11.2). This evolution takes place in a dynamic social, economic, technological, biophysical and political context, which determines the coping ability of a region or country (2). Coping ability is defined here as the degree to which the public health system and individuals can deal successfully with health effects associated with current climate conditions, including climate variability. It therefore reflects autonomous and planned adaptations that have taken place over time and can be considered the adaptation baseline (i.e. what can be done now given current resources, technology, human capital, institutions, etc.). As shown in Figure 11.2, this ability to

FIGURE 11.2 Climate change and coping ability. The top panel depicts the situation of a country with a well-developed public health system, able to successfully deal with most variations in climate. The second panel depicts a country barely able to deal with the average climate, with little or no capacity to address climate variability. The third panel depicts a situation of increasing coping ability due to investments in adaptation, allowing the country to deal with future mean climate and variability. The last panel shows decreasing coping ability so that even future average climate poses health threats. *Source: adapted from reference 2.*



cope with climate varies from place to place and may change over time, both in response to changes in the factors noted above and to investments in specific adaptations to climate (2).

For example, it has been noted that extreme weather events can have “vastly different consequences for those on whom they infringe because of differences in coping ability (19). There is extensive evidence that an extreme climatic event will result in higher losses of life in a developing country than in a developed country because of limited coping ability (23, 24, 25, 26). Cyclones in Bangladesh in 1970 and 1991 are estimated to have caused 300 000 and 139 000 deaths respectively (27). In contrast, Hurricane Andrew caused 55 deaths when it struck the United States of America in 1992 (although estimated to have caused \$30 billion in damages) (28). Similarly, 62 514 cases of dengue fever were reported in three Mexican states next to Texas (1980–1999) while only 64 cases were reported across the border in Texas itself (12). This large difference has been attributed in part to differences in living conditions, such as the presence of window screens and air conditioning.

Adaptive capacity

Adaptive capacity encompasses coping ability (i.e. what could be implemented now to deal with current climate and climate variability) and strategies, policies and measures that can expand future coping ability. Adaptive capacity is a theoretical construct because it is not possible to know with certainty whether a country will invest resources to expand its coping ability, how technology and other factors will change, or what adaptations actually will be implemented, until a perturbation or stress occurs. For example, access to clean water and adequate sanitation is part of the coping capacity for developed countries and some economies in transition but part of the adaptive capacity of less developed countries (currently not available but possible with investment in water treatment and sanitation facilities). While not certain, it is hoped that both clean water and sanitation will become part of the adaptation baseline for all countries.

Decisions about public health measures unrelated to climate change, such as sanitation and water treatment, may have a profound influence on health consequences associated with climate change. In fact, adaptation strategies frequently are described as risk management and public health programmes can be characterized as reducing climate change health risks (12, 29). Improved weather warning and preparedness systems, buildings and infrastructure, all can be considered measures to reduce human health risks in the event of a changed frequency of weather disasters. However, there is concern that the adaptive capacity to address changes in the magnitude or frequency of extreme climatic conditions may not be very high even though the adaptive capacity to gradual changes in climate may be relatively high (30).

Highly-managed systems, such as agriculture and water resources in developed countries, are thought to be more adaptable (assuming resources to adapt are available) than less-managed or natural ecosystems (20, 31, 32). Similarly, systems that have coped successfully with historical and/or existing stresses are expected to adapt well to stresses associated with future climate change (33). Both these premises assume that a country's coping ability is maintained or enhanced. Unfortunately, there are numerous examples in public health where this capability is not maintained once the health threat has been brought under control. Thirty years ago the threat of infectious diseases appeared to be decreasing due to advances in antibiotic drugs, vaccines, and chemical pesticides among other developments. Today, most health professionals agree that there has been a general resurgence of infectious diseases throughout the world, partly due to the deterioration of public health infrastructures worldwide (34, 35).

These types of simple assumptions concerning adaptability (i.e. highly managed systems are more adaptable, past successes are likely to continue into the future) have formed the basis for broad assessments of sensitivity and adaptability (36). Based on these factors, usually it is asserted that much can and will be done to reduce the impacts of climate change. However, it is not clear how much adaptation actually will take place given the number of uncertainties surrounding climate change adaptation. These include uncertainties about future climate (especially how extremes may change), potential effects and underlying determinants of adaptive capacity (i.e. how future institutions, technologies, skills, knowledge will evolve). In addition, there are many unknowns with respect to costs, feasibility, unintended consequences and effectiveness of adaptations (2).

Determinants of adaptive capacity

Research on adaptive capacity in climate change is very limited and is a key research need (2). However, substantial literature in other fields (economic development, sustainable development, resource management) can provide insights into the likely key determinants of adaptive capacity. These represent conditions that constrain or enhance adaptive capacity and hence the vulnerability of regions, nations and communities. Consideration of these determinants provides another pathway to the overarching goal of protecting and enhancing human health. The IPCC identified the main features of communities or regions that seem to determine their adaptive capacity: economic wealth, technology, information and skills, infrastructure, institutions and equity. In addition, for public health, the current health status and pre-existing disease burdens must be considered.

Economic resources

The economic status of nations, described in terms of GDP, financial capital, wealth, or some other economic measure, clearly is a determinant of adaptive capacity (37, 38). It is widely accepted that wealthy nations have a greater capacity to adapt because they have the economic resources to invest in adaptive measures and to bear the costs of adaptation (20, 39). It is also recognized that poverty is related directly to vulnerability (19, 40) and that the poorest groups in the poorest countries are the most vulnerable to health impacts of climate change (2).

Approximately one-fifth of the world's population lives on less than US \$1 per day. Excluding the three WHO sub-regions with very low child and adult mortality,¹ a strong gradient of increasing child underweight with increasing absolute poverty was found in the remaining eleven (41). Unsafe water and sanitation and indoor air pollution also are associated with absolute poverty in these sub-regions.

The feasibility of adaptation options for many poor countries is constrained by a lack of resources (29). Table 11.1 provides estimates of expenditures on health for the world and by income groups and regions. In 1998 an average of I\$523 per person was spent on health services.² This average varied significantly across both countries and regions, ranging from only I\$82 per person in Africa to I\$2078 in the OECD countries (42). Countries with low health expenditures also have poorer health status. The median health-adjusted life expectancy (HALE) in countries that spend less than I\$200 per capita on health is 47.1 years (43). Adequate expenditure for health care and public health prevention programmes are fundamental needs for adaptation to climatic change (8).

Income growth, improved educational levels and consequent improvements in nutrition and sanitation have contributed to significant improvements in health and declines in mortality in the twentieth century (44, 45). The link between economic resources and health can be illustrated further by consider-

¹ The 191 Member States of the WHO have been divided into five mortality strata on the basis of their level of child and adult male mortality. The matrix defined by the six WHO Regions and the five mortality strata leads to 14 sub-regions, since not every mortality stratum is represented in every region. See WHO 2002 (41) for details.

² The "international dollar" (I\$) estimates are converted from local currency at purchasing power parity rates.

TABLE 11.1 Health spending in 1998, by income groups and regions.

| Income group/region | Total health expenditure (in millions of I\$) | Per capita health expenditure (I\$) | Share of GDP (%) |
|------------------------------------|--|-------------------------------------|------------------|
| World | 3 072 485 | 523 | 7.9 |
| Income group | | | |
| <1000 | 9 985 | 24 | 3.4 |
| 1000–2200 | 156 438 | 88 | 4.5 |
| 2200–7000 | 518 710 | 206 | 5.1 |
| >7000 | 2 387 353 | 2042 | 9.6 |
| Region | | | |
| Africa | 50 170 | 82 | 5.1 |
| Americas | 176 223 | 438 | 7.0 |
| Middle East | 80 932 | 176 | 4.8 |
| Eastern Europe and Central Asia | 99 761 | 281 | 5.7 |
| OECD | 2 317 247 | 2078 | 9.7 |
| South Asia | 141 262 | 95 | 4.4 |
| Asia and Pacific | 206 891 | 142 | 4.4 |

Note: I\$ are converted from local currency at purchasing power parity rates.

Source: reproduced from reference 42. See Poullier et al. for list of countries in region.

ing episodes of sharp economic downturns that reduce a country's resources to invest in public health. Combined with poor policy decisions and implementation, adverse economic conditions led to reductions in health expenditures in many developing countries and countries of the former Union of Soviet Socialist Republics in the 1980s (46).

Research also has begun to reveal the linkage between health and economic growth. While not definitive, this research consistently finds strong relationships between health, as measured by health indicators such as survival rates and life expectancy, and income levels or economic growth rates (47, 48). Simultaneous impacts of health on wealth and vice versa have been found (49). Improvements in health affect economic growth directly—"healthier people are more productive"—and indirectly, through effects on demography (45). Research on the effects of geography and climate on income suggests that the interaction of tropical climate and diseases, particularly malaria, can significantly affect economic performance (50). Another study found that lagging health and agriculture technology in the tropics opened a substantial income gap between climate zones (51). Other researchers found that the much route by which "tropics, germs, and crops" affect economic development is through institutions, rather than by directly affecting countries' incomes (52).

Technology

Advances in technology, such as new drugs or diagnostic equipment, can increase substantially our ability to solve health problems (53). More generally, the availability and access to technology at the individual, local, and national levels, in key sectors (e.g. agriculture, water resources, health) is an important determinant of adaptive capacity (2). Many of the adaptive strategies that protect human health involve technology (e.g. warning systems, air conditioning, pollution controls, housing, storm shelters, vector control, vaccination, water treatment and sanitation). While much of this technology is well established (water treatment,

sanitation), some is relatively new and still being disseminated (well-equipped mobile laboratories, computer information and reporting systems which can support disease surveillance). In other cases there is a need for new technologies (new vaccines and pesticides) to enhance the ability to cope with a changing climate. Countries that are open to the use of technologies and can develop and disseminate new technologies have enhanced adaptive capacity (2).

It is important to assess in advance any risks to health from proposed technological adaptations (11, 13, 22). Increased use of air conditioning would protect against heat stress but could increase emissions of both greenhouse gases and conventional air pollutants. Similarly, if new pesticides are used to control disease vectors their effects on human health, insect predators, and increased insect resistance to pesticides all need to be considered (11, 12). New chemicals or treatments for vector control must be effective but their breakdown products should be non-toxic and non-persistent. The migration of potentially hazardous compounds into air and water should be avoided.

Information and skills

In general, countries with higher levels of “human capital” or knowledge are considered to have greater adaptive capacity (54). The UN reports that more than 850 million people in developing countries are illiterate and about 90 million children worldwide are denied any schooling, raising concerns about their vulnerability to a range of problems (55). Table 11.2 provides estimates of illiteracy rates by income group and region. Illiteracy, as well as poverty, has been listed as a key determinant of low adaptive capacity in north-east Brazil (56). As many adaptive measures involve implementation of effective health education programmes, a high level of illiteracy can seriously compromise their effectiveness. Some of the simple, low-cost, low-technology measures to reduce health effects (e.g. using sari cloth to filter drinking water, removing containers around dwellings that provide habitat for disease vectors) involve educating the public on the feasibility and effectiveness of such measures.

TABLE 11.2 Illiteracy rates in 2000, by income groups and regions.

| Income group/region | Illiteracy rate, adult male (% males ages 15 and above) | Illiteracy rate, adult female (% females ages 15 and above) |
|------------------------------|--|--|
| World | 17.02 | 30.31 |
| Income group | | |
| Low income | 28.29 | 46.85 |
| Lower middle income | 9.22 | 21.47 |
| Middle income | 9.17 | 19.51 |
| Upper middle income | 8.95 | 10.82 |
| High income | ... | ... |
| Region | | |
| East Asia and Pacific | 8.09 | 21.16 |
| Europe and Central Asia | 1.38 | 4.05 |
| Latin America and Caribbean | 10.7 | 12.5 |
| Middle East and North Africa | 24.85 | 45.96 |
| South Asia | 33.85 | 57.3 |
| Sub-Saharan Africa | 30.14 | 46.66 |

Source: reproduced from reference (57). See the World Development Indicators database of list of countries in region.

Lack of trained and skilled personnel may restrict a nation's ability to implement adaptation measures (11). Health systems in particular are labour intensive and require qualified and experienced staff to function well (53). Health "human capital" can be increased through investment in education and training. Human capital does not deteriorate with use, but can depreciate as old skills become obsolete with the advent of new knowledge, methods, and technologies (53). In addition, individuals' retirement and/or deaths result in the loss of their skills and accumulated knowledge.

Effective adaptation will require individuals skilled at recognizing, reporting and responding to health threats associated with climate change. Researchers trained in epidemiology and laboratory research will be needed to provide a sound basis for surveillance and response. Social scientists can contribute to an understanding of social behaviours and demographics as they relate to causes and control of diseases. Skilled public health managers, who understand surveillance and diagnostic information, will be needed to mobilize the appropriate response. People trained in the operation, quality control and maintenance of public health infrastructure, including laboratory equipment, communications equipment, and sanitation, wastewater, and water supply systems also are required (53).

Infrastructure

Adaptive capacity is likely to vary with the level of a country's infrastructure (2) (see Table 11.3 for estimates of access to water supply and sanitation infrastructure). Adaptive responses to health impacts of climate change are enhanced by infrastructures specifically designed to reduce vulnerability to climate variability (e.g. flood control structures, air conditioning, building insulation, stringent building codes, etc.) and general public health infrastructures (e.g. sanitation facilities, waste water treatment, water supply systems, laboratory buildings).

Infrastructure such as roads, rails and bridges, water systems and drainage, mass transit and buildings can reduce vulnerability to climate change (2). It also has the potential to be adversely impacted (especially if immovable), which can increase vulnerability to climate change. Flooding can overwhelm sanitation infrastructure and lead to water-related illnesses (8, 12). After Hurricane Mitch hit Central America, severe damage to the transportation infrastructure made it more difficult to assist affected populations (2). Similarly, damage to transporta-

TABLE 11.3 Water supply and sanitation coverage in 2000 by region (% of population served).

| Region | Water Supply | | | Sanitation | | |
|---------------------------------|--------------|-------|-------|------------|-------|-------|
| | Total | Urban | Rural | Total | Urban | Rural |
| World | 82 | 94 | 71 | 60 | 86 | 38 |
| Region | | | | | | |
| Africa | 62 | 85 | 47 | 60 | 84 | 45 |
| Asia | 81 | 93 | 75 | 48 | 78 | 31 |
| Latin America and the Caribbean | 85 | 93 | 62 | 78 | 87 | 49 |
| Oceania | 88 | 98 | 63 | 93 | 99 | 81 |
| Europe | 96 | 100 | 87 | 92 | 99 | 74 |
| Northern America | 100 | 100 | 100 | 100 | 100 | 100 |

Source: reproduced from reference 58. See WHO and UNICEF, 2000 for list of countries in region.

tion infrastructure during the east Africa floods of 1998 and Mozambique floods in 2000 hampered relief efforts (2).

Institutions

Social institutions are considered an important determinant of adaptive capacity. Those countries with less-effective institutional arrangements, commonly developing nations and those in transition, have a lower capacity to adapt than countries with well-established and effective institutions (2). Inadequate institutional support frequently is cited as a hindrance to adaptation. Institutional deficiencies and managerial weaknesses are cited as contributing to Bangladesh's vulnerability to climate change (2). The Democratic People's Republic of Korea experienced strong storms with torrential rain in 1995 and 1996, followed by droughts in 1997 and 1998. Estimates of deaths from famine since 1995 range from 220 000 to 2 million (59). While there were widespread crop failures, the agricultural system's inability to meet the needs of the people is not new. Other features of this society including economic isolation, lack of reserves, highly centralized arrangements for storage and redistribution of foods, lack of variety in agricultural practice and a strictly hierarchical political system exacerbated the situation (60). The IPCC (2) cites "institutional inertia" in the Asia region as limiting investment in environmental protection and increasing climate risks. Inconsistent and unstable agricultural policies have increased the vulnerability of food production in Latin America (2). Political upheavals in African countries, with the accompanying political and economic instability, constrain the implementation of adaptation measures (2). Health systems should offer protection against disease, because of economic and social crises these have (in extreme cases) either collapsed or not been built in many countries (35).

The complex interaction of issues expected with climate change will require new arrangements and collaborations between institutions to address risks effectively, thereby enhancing adaptive capacity. The Environmental Risk Management Authority in New Zealand involves collaboration between the health, forestry, environment and conservation sectors (8). Similarly, nations and international organizations such as WHO can cooperate in coordinating surveillance and response activities to address disease threats more effectively (34).

Finally, increased collaboration between the public and private sectors can enhance adaptive capacity. The Medicines for Malaria venture—a joint initiative by the public and private sectors to develop new antimalarial drugs—is developing new products for use in developing countries (53). Another example is drug donations by industry to help eliminate infectious diseases in developing countries (53). Such collaborations have the potential substantially to reduce health impacts associated with climate change.

Equity

Frequently it is argued that adaptive capacity will be greater if access to resources within a community, nation, or Earth is distributed equitably (2, 61, 62). Universal access to quality services is a bedrock principle of public health. However, while many have broad and advanced access to health care, many have been denied access. WHO estimates that the developing world carries 90% of the disease burden, yet poorer countries have access to only 10% of the resources for health (53).

Demographic variables such as age, gender, ethnicity, educational attainment and health often are cited in the literature as related to the ability to cope with risk (11, 37, 63). WHO notes that for a large group of people long-term unemployment results in exclusion from the mainstream of development and society (64). The combination of homelessness and lack of access to financial resources and infrastructure restricts adaptation options (2). Similar conclusions about the marginalization of minority groups have been drawn (65).

Health status and pre-existing disease burdens

Population well-being is an important ingredient and determinant of adaptive capacity. Table 11.4 provides estimates of deaths and disability-adjusted life years for 2001 (41). Great progress has been achieved in public health, particularly through the improvement of drinking water and sanitation; development of national health systems; introduction of antibiotics and mass immunization; and the improvement of nutrition. Yet 170 million children in poor countries are underweight: over 3 million of them die each year as a result. The African region remains the region most affected by infectious and parasitic diseases. Malaria, HIV/AIDS, childhood vaccine preventable diseases and diarrhoea represent the highest estimated deaths in Africa. Malaria is estimated to have caused 963000 deaths and the loss of around 36 million years of “healthy” life in this region in 2001.

Non-communicable diseases, in particular cardiovascular diseases, represent the highest mortality in countries with very low child and adult mortality. However, they are now becoming more prevalent in developing nations, where they create a double burden of disease—a combination of long-established infectious diseases and increasing chronic, noncommunicable diseases. For example, countries in south-east Asia with high child and adult mortality show an estimated 2.7 million deaths from infectious and parasitic diseases, 3.2 million from cardiovascular diseases.

Research needs

Few studies of climate change and health go beyond identifying adaptation options that might be possible and/or incorporating simplified representations of adaptive responses. It is important to improve understanding of the process of adaptation. This includes gaining better knowledge of the processes of adaptation decision-making; roles and responsibilities in adaptation of individuals, communities, nations, institutions and the private sector; conditions that stimulate or act as a barrier to adaptation; and what level of certainty is needed for public health decision-makers to act.

Research on barriers and opportunities for enhancing adaptive capacity in order to protect human health, as well as potential interactions with ongoing development projects and programmes, also is a key research need.

Determining the benefits of health adaptations—reduction in the effects of climate change on health—is likely to be complex and controversial. In general, there is little scientific literature on the population burden of disease attributable to current or future climate change (2) (but see chapter seven), and much less on the economic and non-economic valuation of those effects. There is therefore little basis for making aggregate estimates of the costs avoided (or benefits gained) by successful adaptation measures to compare with the costs of such

TABLE 11.4 Deaths and burden of disease in DALYs in 2001, by mortality stratum in WHO Regions (in thousands).

| Region and mortality stratum | Deaths | | | Disability-adjusted Life Years (DALYs) | | | | |
|------------------------------|--------|--------------|-----------------|--|--------------|-----------------|----------|--------|
| | Total | Communicable | Noncommunicable | Injuries | Communicable | Noncommunicable | Injuries | |
| World | 56554 | 18374 | 33077 | 5103 | 1467257 | 615737 | 672865 | 178656 |
| Region | | | | | | | | |
| <i>Africa</i> | | | | | | | | |
| High child and adult | 4365 | 2968 | 1098 | 298 | 147899 | 105097 | 30030 | 12771 |
| High child, very high adult | 6316 | 4615 | 1264 | 437 | 209985 | 156359 | 36075 | 17551 |
| <i>The Americas</i> | | | | | | | | |
| Very low child and adult | 2747 | 172 | 2400 | 176 | 46520 | 3250 | 38642 | 4628 |
| Low child and adult | 2619 | 485 | 1810 | 324 | 81270 | 17105 | 50328 | 13837 |
| High child and adult | 544 | 198 | 288 | 57 | 17427 | 6761 | 8432 | 2235 |
| <i>Eastern Mediterranean</i> | | | | | | | | |
| Low child and adult | 707 | 126 | 475 | 106 | 23007 | 5691 | 13282 | 4034 |
| High child and adult | 3449 | 1700 | 1454 | 295 | 113214 | 61446 | 39329 | 12439 |
| <i>Europe</i> | | | | | | | | |
| Very low child and adult | 4076 | 236 | 3643 | 197 | 53075 | 2579 | 46259 | 4237 |
| Low child and adult | 1969 | 193 | 1664 | 113 | 38936 | 7029 | 27473 | 4434 |
| Low child, high adult | 3658 | 157 | 3048 | 453 | 59212 | 4999 | 42170 | 12042 |
| <i>South-east Asia</i> | | | | | | | | |
| Low child and adult | 2194 | 644 | 1275 | 275 | 61290 | 20403 | 31866 | 9021 |
| High child and adult | 12273 | 5171 | 5913 | 1188 | 357554 | 167749 | 144703 | 45102 |
| <i>Western Pacific</i> | | | | | | | | |
| Very low child and adult | 1161 | 138 | 939 | 84 | 16430 | 1064 | 13720 | 1646 |
| Low child and adult | 10475 | 1572 | 7805 | 1098 | 241438 | 56205 | 150556 | 34677 |

Source: reproduced from reference 41. See WHO, 2002 for definitions of mortality stratum and list of countries in sub-region.

measures. Information on costs and benefits of adaptation measures is likely to be important for decision-makers.

Finally, integrated frameworks will be needed to evaluate adaptation options. Designing such frameworks is challenging because they must organize information from a wide array of sources, including: epidemiological studies; models that incorporate identified exposure-response relationships to project future health outcomes; adaptation options; cost and effectiveness analyses; monitoring and evaluation systems; and feedback from decision-makers.

Conclusions

Building capacity is an essential step in preparing adaptation strategies. Education, awareness raising and the creation of legal frameworks, institutions and an environment that enables people to take well-informed, long-term, sustainable decisions, all are needed. Building adaptive capacity in public health will require a forward-looking, strong and unifying vision of health care in the twenty-first century as well as an understanding of the problems posed by climate change. However, it must be stressed that adapting to climate change will require more than financial resources, technology, and public health infrastructure. Human resources and knowledge are critical; institutions that are committed to and support the goals articulated in "Health for All by the Year 2000" are essential. The public health community is in a key position to help nations face the health challenges associated with climate change.

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