Health consequences of global climate change

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In the closing decades of the twentieth century, the topic of environment and health acquired new and troubling dimensions. The health risks posed by stratospheric ozone depletion, global climate change, nitrogen loading of the biosphere, worldwide depletion of fertile land and freshwater supplies and an accelerating loss of biodiversity were not recognized even thirty years ago. They are a consequence of the continuing growth in human numbers, with intensification of economic activity and generation of wastes.

One of the most widely discussed of these issues is climate change. In 1996, the UN’s Intergovernmental Panel on Climate Change concluded that man-made changes in the global atmosphere were probably already beginning to change world climate$. During 1997 and 1998, global temperatures reached their highest levels since record-keeping began in the mid-nineteenth century. Overall, ten of the twelve hottest years of the twentieth century occurred after 1988.

Global climate change would affect human health via paths of varying complexity, scale and directness. There would be positive as well as negative effects, but in global terms the negative are expected to predominate substantially$. The more direct health impacts of climate change include those due to changes in exposure to weather extremes (heatwaves, winter cold), those due to increased production of certain air pollutants and aerosolized spores and moulds and those due to increases in other extreme weather events (floods, cyclones, storm-surge, droughts). Climate change would affect infectious disease transmission and regional food productivity (especially cereal grains) by essentially indirect mechanisms. In the longer term, these indirect impacts on human health would probably be of greater magnitude than the more direct impacts$.

Demographic and economic disruption may, eventually, be a great source of adverse health impact as millions of people are displaced by shoreline erosion, coastal flooding and agricultural decline. Health impacts associated with population displacement fall under two general categories—those due to disruption of the local environment, and those attributable to substitute environ-

ments such as refugee camps where people are at risk of parasitic and communicable diseases such as malaria and cholera, respiratory infections, intestinal disorders, malnutrition and psychological stress$. A rise in sea-level would affect the health and wellbeing of coastal populations in diverse ways—direct and indirect, cumulative and episodic.

THE TIMING OF HEALTH IMPACTS

The first detectable changes may well be alterations in the geographic range (latitude and altitude) and seasonality of certain vector-borne infectious diseases. Already there is debate over whether recent increases of malaria and dengue in highland regions around the world are due to climatic or other factors$. There are several other categories of likely early health impact. Hot weather, especially if sunny conditions prevail, would amplify the production of noxious photochemical smog in urban areas, particularly where petroleum-combusting traffic is dense. Summer-time foodborne infections (e.g. Salmonella enteritidis infections) may show longer-lasting annual peaks.

Other health impacts may not become evident for several decades—those of the disturbance of natural and managed food-producing ecosystems (on land and at sea), of rising sea-level with its many physical, ecological, social and economic consequences, and of population displacement for reasons of physical hazard, land loss, economic disruption and civil strife.

The point at which the health impacts of climate change become detectable will depend particularly upon the sensitivity of response (i.e. how steep is the rate of increase in the health outcome per unit increase in climate-induced ‘exposure’) and whether there is a threshold in the response function that results in a ‘step’. Detectability will also be influenced by the availability of high-quality data and by the background variability in the health-related index in question.

With respect to vector-borne infectious diseases, a continuation of recent climatic trends is likely to cause some marginal shifts in the geographic range and seasonality of diseases such as malaria and dengue fever. There have been reports of malaria, dengue fever and their vector mosquitoes occurring at increasingly high altitudes in Africa, Asia and Latin America$, however, such shifts would also depend on local topographical and ecological

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circumstances, on other determinants of local population vulnerability and on the existence and level of adaptive public health defences. As with climate change itself, there is an inherent difficulty in both the detection of change in health outcome and the attribution of its causes.

HEALTH IMPACT ASSESSMENT: METHODS AND DIFFICULTIES

Research strategies

Epidemiologists face a challenge in estimating the future health impacts of climate change\(^2\). There are three different strategies for assessing impacts. Researchers can extrapolate from previous natural events that approximate to aspects of future climate change. Such analogous situations might be either sustained trends such as warming or short-term fluctuations (which may become an increasingly important aspect of world climatic conditions in a warmer world). Or they might seek early evidence by examining indicators of health risk or health status that are especially \textit{climate-sensitive}. (Though related to the preceding item, this second strategy depends on the existence of identifiable global environmental change, or of some local manifestation of that larger-scale change.) Or researchers might use existing knowledge and theory to construct \textit{mathematical models} of likely health outcomes. This entails conducting risk assessments in relation to \textit{future} environmental developments—‘scenario-based’ health risk assessment. The inherent complexity and dynamic properties of the climate system and climate-sensitive ecological systems mean that, under conditions of climate change, we should expect interactions, feedbacks, threshold phenomena and surprises.

Difficulties for researchers

The task of assessing the actual and potential health impacts of climate change poses four particular challenges to scientists.

First, man-made climate change is expected to be gradual and long-term. Changes in certain health outcomes may already be occurring in response to the recent and continuing change in world climate (whatever the cause of that change). The identification of cause and effect—the demonstration that such health effects result from long-term changes in background climatic conditions—will require pooling of epidemiological data or replication of studies. There will be few early results from this type of research.

Second, in empirical epidemiological studies there are nearly always difficulties in estimating the role of climate \textit{per se} as a cause of change in health status. Most diseases have multiple contributory ‘causes’ and when several of the known or suspected causal factors are present their relative contributions can be difficult to apportion. This difficulty is well recognized by epidemiologists as the ‘confounding’ of effects.

Third, populations vary in their ‘vulnerability’ to climate stress. This variation may reflect either endogenous characteristics (such as nutritional or immune status in relation to infectious disease) or contextual circumstances that influence the ‘sensitivity’ of the population’s response to the climate change (such as access to air-conditioning during heatwaves).

Fourth, the assessment of scenario-based health risks with mathematical models must address the issues of validity, uncertainty and contextual realism. Validity refers to the difficulty of obtaining adequate representation of the central set of environmental and biological relationships, and of the interacting ecological and social processes that influence the impact of those upon health. Uncertainty is generated by the complex configuration of causal and modifying factors. And the contextual difficulty is that climate change is not the sole global environmental change that impinges on human health.

Examples of simulation modelling of health impacts

The use of mathematical models to foresee, or ‘simulate’, the future health impacts of climate change requires working from projected global or regional climatic scenarios, as modelled by climatologists for, say, the 2020s and 2050s. To these ‘time-slice’ scenarios we apply our existing knowledge about how climatic variation affects a particular health outcome. For example, if we know how death rates in certain cities are affected by heatwaves in today’s world, we can estimate how those urban populations would respond to a future summer season in which the frequency of heatwaves is tripled.

A more complex task is to estimate how climatic changes would affect the potential geographic range of transmission of mosquito-borne infectious diseases such as malaria and dengue fever. Vector-borne diseases are maintained in complex cycles that involve blood-feeding arthropod vectors (and sometimes reservoir host species, predominantly mammals and birds) that depend on specific ecological conditions for survival. As mentioned above, these diseases are very sensitive to climatic conditions, and response patterns vary between diseases. Thus, for some vector-borne diseases (including malaria and dengue fever), increased temperatures will tend to expand the latitudinal and altitudinal range of potential transmission. Higher temperatures, in combination with conducive patterns of rainfall and surface water, may extend the transmission season in currently marginal locations. On the other hand, for some vector-borne diseases (such as schistosomiasis, by
affecting snail breeding and survival) in some locations, climate change may decrease potential transmission.

Considerable effort has gone into developing mathematical models for such projections, and they indicate that the coming century will see an increase in the proportion of world population living in regions of potential transmission of malaria and dengue fever. For malaria, the most recent research indicates that the additional increase would be of the order of an extra 300 million people in 2080 (against a baseline expectation of several billions). This would be supplemented by a widespread increase in the seasonal duration of transmission in both current and prospective areas of malaria transmission. The limitation of greenhouse gas emissions to achieve stabilization of CO₂ concentration at 550–750 ppm would reduce those increases by around one-third.

Modelling studies have similarly examined the impacts of climate change upon cereal grain yields (which account for about two-thirds of world food energy). With allowance for a range of future trends in trade and economic development, they indicate that yields would increase at high and mid-latitudes, but decrease at lower latitudes—a disparity that would become more pronounced with time. These analyses indicate that, by the 2080s, the additional number of people at risk of hunger due to climate change will be 80–100 million people (plus-or-minus 10 million due to natural variability) out of the estimated 10 billion population. In that study, Africa accounts for between 60 and 70 million of the extra people at risk of hunger by the 2080s.

**POPULATION VULNERABILITY, AND ADAPTATION**

Human populations vary in their vulnerability to certain health outcomes. Vulnerability is a function of the extent to which a health outcome is sensitive to climate change and of the capacity of the population to adapt to new climate conditions. A population’s vulnerability depends on factors such as population density, level of economic development, food availability, local environmental conditions, pre-existing health status and the quality and availability of public health care. Woodward and colleagues have identified five structural causes of population vulnerability to ill-health—uncontrolled economic growth that damages resource infrastructure; poverty; political rigidity; unconstrained economic ‘growth’ dependency; and geographic isolation. With the partial exception of the first two, each of these acts principally by reducing the population’s capacity for adaptive response. The continued poverty (and associated lack of technological resources, professional skills and community education) of many populations creates a particular ‘constitutional’ vulnerability to the impacts of climate change.

**Adaptation to limit adverse health impacts**

Adaptation refers to actions taken to lessen the impact of the anticipated climate change. There is a hierarchy of control strategies that can help to protect population health, categorized as (i) administrative or legislative; (ii) engineering or (iii) personal or behavioural. Adaptation, which will be either reactive or anticipatory, can be undertaken at international/national, community or individual level.

The reduction of socioeconomic vulnerability remains a priority. The poor are likely to be at greatest health risk because of their lack of access to material and information resources. The long-term reduction in health inequalities will require income redistribution, full employment, better housing and an improved public health infrastructure. Services that have a direct impact on health, such as primary care, disease control, sanitation and disaster preparedness and relief, must also be enhanced. The vulnerability of the poor may jeopardize the wellbeing of more advantaged members of the same population. Examples of ‘spillover’ effects include spread of infectious diseases from primary foci in poor populations, and the opportunity cost of public services committed to dealing with problems related to disadvantage.

The environmental management of health-supporting ecosystems (e.g. freshwater resources and agricultural areas) should be improved. A good example is the control of water-borne infections. In many areas, increased density of rainfall is likely to lead to more frequent occurrence of infections such as giardiasis and cryptosporidiosis. Traditional public health interventions that focus entirely on personal hygiene and food safety are of limited effectiveness. A broader approach would take into account the interactions between climate, vegetation, agricultural practices and human activity—and would result in recommendations for the type, time and place of ‘upstream’ public health interventions such as changes in management of water catchment areas.

The infrastructure of national public health is critical to adaptation strategies. The 1990s witnessed the resurgence of several major diseases once thought to have been controlled, such as tuberculosis, diphtheria and certain sexually transmitted infections. Malaria is increasing again in many parts of the world. Environmental control programmes are weaker and less rigorously enforced than they were a few decades ago. For example, in Madagascar, Ethiopia and the highlands of Zambia there has been a progressive increase in malaria because of the collapse of the insecticide spraying programme.
Elementary adaptation to climate change can be facilitated by improving the monitoring and surveillance systems. Basic indices of population health status (e.g. life expectancy) are available for most countries. However, morbidity surveillance varies widely according to locality and the disease in question. To monitor disease incidence/prevalence—which may often provide a sensitive index of impact—low-cost data from primary care facilities could be collected in sentinel populations.

These top-down approaches must be widely supplemented by bottom-up approaches to adaptation at the community and individual levels. These would include local environmental management, urban design, public education, neighbourhood alert and assistance schemes and individual behavioural changes.

CONCLUSION

With the advent of global climate change we need to think about environmental health not only within the framework of environment-as-hazard but also within the framework of biosphere-as-habitat. We are living in a profoundly important transitional period in the career of the human species. For the first time in history, globally, we have begun to overload various of the biosphere’s life-supporting systems. This is most obvious in the incipient changes in the global climate system now occurring in response to human-induced changes to the composition of the troposphere. That these changes will adversely affect human health is near-certain. Local environmental health hazards are an important focus of research and policy concern, but we must also apply our knowledge and understanding to the likely health impacts of global climate change. Such forecasts, incorporated into the wider policy-making debate, will contribute both to preventive action (i.e. mitigation of greenhouse gas emissions) and to adaptations that will lessen the adverse effects on human health.

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