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Research Paper

Climatic Change and Health Impact

Geography

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ABSTRACT

Today, worldwide, there is an apparent increase in many infectious diseases, including some newly-circulating ones (HIV/AIDS, hantavirus, hepatitis C, SARS, etc.). This reflects the combined impacts of rapid demographic, environmental, social, technological and other changes in our ways of living. Climate change will also affect infectious disease occurrence.1

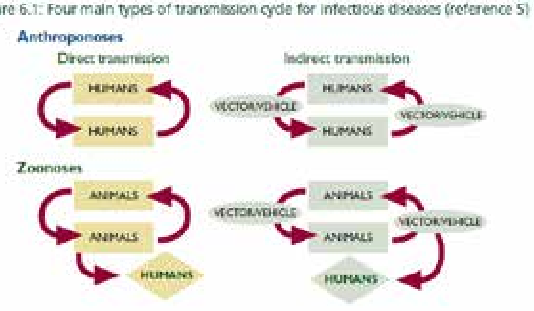
To inform policies, an estimation of the approximate magnitude of the health impacts of climate change is needed. This will indicate which particular impacts are likely to be greatest and in which regions, and how much of the climate-attributable disease burden could be avoided by emissions reduction. It will also guide health-protective strategies.

Sustainability is essentially about maintaining Earth's ecological and other biophysical life-support systems. If these systems decline, human population wellbeing and health will be jeopardized. Technology can buy time, but nature's bottom-line accounting cannot be evaded. We must live within Earth's limits. The state of human population health is thus a central consideration in the transition towards sustainability.6

Humans have known that climatic conditions affect epidemic diseases from long before the role of infectious agents was discovered, late in the nineteenth century. Roman aristocrats retreated to hill resorts each summer to avoid malaria. South Asians learnt early that, in high summer, strongly curried foods were less likely to cause diarrhoea.

Infectious agents vary greatly in size, type and mode of transmission. There are viruses, bacteria, protozoa and multicellular parasites. Those microbes that cause "anthroponoses" have adapted, via evolution, to the human species as their primary, usually exclusive, host. In contrast, non-human species are the natural reservoir for those infectious agents that cause "zoonoses" (Fig 6.1). There are directly transmitted anthroponoses (such as TB, HIV/AIDS, and measles) and zoonoses (e.g., rabies). There are also indirectly-transmitted, vectorborne, anthroponoses (e.g., malaria, dengue fever, yellow fever) and zoonoses (e.g. bubonic plague and Lyme disease).

Figure 6.1: Four main types of transmission cycle for infectious diseases (reference 5)



Vector-borne and water-borne diseases

Important determinants of vector borne disease transmission include: (i) vector survival and reproduction, (ii) the vector's biting rate, and (iii) the pathogen's incubation rate within the vector organism. Vectors, pathogens and hosts each survive and reproduce within a range of optimal climatic conditions: temperature and precipitation are the most important, while sea level elevation, wind, and daylight duration are also important.

Human exposure to waterborne infections occurs by contact with contaminated drinking water, recreational water, or food. This may result from human actions, such as improper disposal of sewage wastes, or be due to weather events. Rainfall can influence the transport and dissemination of infectious agents, while temperature affects their growth and survival.

Observed and predicted climate/infectious disease links

There are three categories of research into the linkages between climatic conditions and infectious disease transmission. The first examines evidence from the recent past of associations between climate variability and infectious disease occurrence. The second looks at early indicators of already-emerging infectious disease impacts of long term climate change. The third uses the above evidence to create predictive models to estimate the future burden of infectious disease under projected climate change scenarios.

Historical Evidence

There is much evidence of associations between climatic conditions and infectious diseases. Malaria is of great public health concern, and seems likely to be the vector-borne disease most sensitive to long-term climate change. Malaria varies seasonally in highly endemic areas. The link between malaria and extreme climatic events has long been studied in India, for example. Early last century, the river-irrigated Punjab region experienced periodic malaria epidemics. Excessive monsoon rainfall and high humidity was identified early on as a major influence, enhancing mosquito breeding and survival. Recent analyses have shown that the malaria epidemic risk increases around five-fold in the year after an El Niño event.[2]

Early impacts of climate change

These include several infectious diseases, health impacts of temperature extremes and impacts of extreme climatic and weather events.

Predictive Modeling

The main types of models used to forecast future climatic influences on infectious diseases include statistical, process-based, and landscape-based models.[3] These three types of model address somewhat different questions.

Statistical models require, first, the derivation of a statistical (empirical) relationship between the current geographic distribution of the disease and the current location specific climatic conditions. This describes the climatic influence on the actual distribution of the disease, given prevailing levels of human intervention (disease control, environmental management, etc.). By then applying this statistical equation to future climate scenarios, the actual distribution of the disease in future is estimated, assuming unchanged levels of human intervention within any particular climatic zone. These models have been applied to climate change impacts on malaria, dengue fever and, within the USA, encephalitis. For malaria some models have shown net increases in malaria over the coming half century, and others

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little change.

Process-based (mathematical) models use equations that express the scientifically documented relationship between climatic variables and biological parameters – e.g., vector breeding, survival, and biting rates, and parasite incubation rates. In their simplest form, such models express, via a set of equations, how a given configuration of climate variables would affect vector and parasite biology and, therefore, disease transmission. Such models address the question: "If climatic conditions alone change, how would this change the potential transmission of the disease?" Using more complex "horizontal integration", the conditioning effects of human interventions and social contexts can also be incorporated.

This modeling method has been used particularly for malaria and dengue fever.[4] The malaria modeling shows that small temperature increases can greatly affect transmission potential. Globally, temperature increases of 2-3ºC would increase the number of people who, in climatic terms, are at risk of malaria by around 3- 5%, i.e. several hundred million. Further, the seasonal duration of malaria would increase in many currently endemic areas.

Since climate also acts by influencing habitats, landscape based modeling is also useful. This entails combining the climate-based models described above with the rapidly-developing use of spatial analytical methods, to study the effects of both climatic and other environmental factors (e.g. different vegetation types – often measured, in the model development stage, by ground-based or remote sensors). This type of modeling has been applied to estimate how future climate-induced changes in ground cover and surface water in Africa would affect mosquitoes and tsetse flies and, hence, malaria and African sleeping sickness.

How much disease would climate change cause? To inform policies, an estimation of the approximate magnitude of the health impacts of climate change is needed. This will indicate which particular impacts are likely to be greatest and in which regions, and how much of the climate-attributable disease burden could be avoided by emissions reduction. It will also guide health-protective strategies.

Climate change and Human Health – Risk & responses

The global burden of disease attributable to climate change has recently been estimated as part of a comprehensive World Health Organization project.1 This project sought to quantify disease burdens attributable to 26 environmental, occupational, behavioural and lifestyle risk factors in 2000, and at selected future times up to 2030.

Disease burdens and summary measures of population health

The disease burden comprises the total amount of disease or premature death within the population. To compare burden-fractions attributable to several different risk factors requires, first, knowledge of the severity/disability and duration of the health deficit, and, second, the use of standard units of health deficit. The widelyused Disability-Adjusted Life Year (DALY2) is the sum of:

- years of life lost due to premature death (YLL)
- years of life lived with disability (YLD).

YLL takes into account the age at death. YLD takes into account disease duration, age at onset, and a disability weight reflecting the severity of disease.

To compare the *attributable* burdens for disparate risk factors we need to know: (i) the baseline burden of disease, absent the particular risk factor, (ii) the estimated increase in risk of disease/death per unit increase in risk factor exposure (the "relative risk"), and (iii) the current or estimated future population distribution of exposure. The *avoidable* burden is estimated by comparing projected burdens under alternative exposure scenarios.

Disease burdens have been estimated for five geographical regions (Figure 7.1). The attributable disease burden has been estimated for the year 2000. For the years 2010, 2020 and 2030, the climate-related relative risks of each health outcome under each climate change scenario, relative to the situation if climate change did not occur, were estimated.3 The baseline scenario is 1990 (the last year of the period 1961 to 1990 – the reference period used by the World Meteorological Organization and IPCC).

The future exposure scenarios assume the following projected GHG emission levels:

1. Unmitigated emission trends (approximating the IPCC "IS92a" scenario)
2. Emissions reduction, achieving stabilization at 750 ppm CO2-equivalent by 2210 (s750)

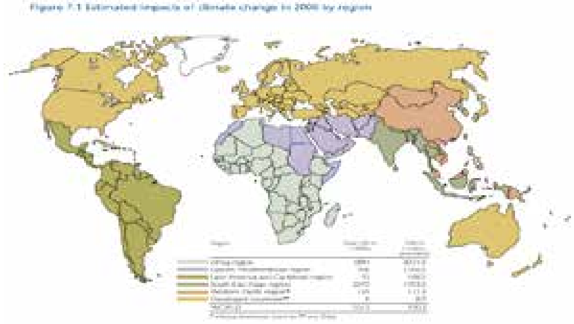

Table 7.1: Health outcomes considered in this analysis

Type of outcome	Outcome	Incidence/ Prevalence
Food and water-borne disease	Diarrhoea episodes	Incidence
Vector-borne disease	Malaria cases	Incidence
Natural disasters*	Fatal unintentional injuries	Incidence
Risk of malnutrition	Non-availability of recommended daily caloric intake	Prevalence

*All natural-disaster impacts are separately attributed to coastal floods and to inland floods/ landslides

3. More rapid emissions reduction, stabilizing at 550 ppm CO2-equivalent by 2170 (s550).

Health outcomes assessed

Only some of the health outcomes associated with climate change are addressed here (Table 7.1). These were selected on the basis of:

(a) sensitivity to climate variation,
(b) predicted future importance, and
(c) availability/feasibility of quantitative global models.

Additional likely health impacts that are currently not quantifiable include those due to:

- changes in air pollution and aeroallergen levels
- altered transmission of other infectious diseases
- effects on food production via climatic influences on plant pests and diseases
- drought and famine
- population displacement due to natural disasters, crop failure, water shortages
- destruction of health infrastructure in natural disasters
- conflict over natural resources
- direct impacts of heat and cold (morbidity).

All independently-published models linking climate change to quantitative, global, estimates of health impacts (or health-affecting impacts – e.g. food yields) were reviewed. Where global models do not exist, local or regional projections were extrapolated. Models were selected according to their assessed validity. Linear interpolation was used to estimate relative risks for inter-scenario years.

Summary of results

Climate change will affect the pattern of deaths from exposure to high or low temperatures. However, the effect on actual disease burden cannot be quantified, as we do not know to what extent deaths during thermal extremes are in sick/frail persons who would have died soon anyway.

In 2030 the estimated risk of diarrhoea will be up to 10% higher in some regions than if no climate change occurred. Since few studies have characterized this particular exposure-response relationship, these estimates are uncertain.

Estimated effects on malnutrition vary markedly among regions. By 2030, the relative risks for unmitigated emissions, relative to no climate change, vary from a significant increase in the South- East Asia region to a small decrease in the Western Pacific. Overall, although the estimates of changes in risk are somewhat unstable because of regional variation in rainfall, they refer to a major existing disease burden entailing large numbers of people.

The estimated proportional changes in the numbers of people killed or injured in coastal floods are large, although they refer to low absolute burdens. Impacts of inland floods are predicted to increase by a similar proportion, and would generally cause a greater acute rise in disease burden. While these proportional increases are similar in developed and developing regions, the baseline rates are much higher in developing countries.

Changes in various vector-borne infectious diseases are predicted. This is particularly so for malaria in regions bordering current endemic zones. Smaller changes would occur in currently endemic areas. Most temperate regions would remain unsuitable for transmission, because either they remain climatically unsuitable (e.g., most of Europe) or socioeconomic conditions are likely to remain unsuitable for reinvasion (e.g., southern United States). Uncertainties relate to how reliable is extrapolation between regions, and to whether potential transmission will become actual transmission.

Conclusion

Changes in infectious disease transmission patterns are a likely major consequence of climate change. We need to learn more about the underlying complex causal relationships, and apply this information to the prediction of future impacts, using more complete, better validated, integrated, models.

Application of these models to current disease burdens suggests that, if our understanding of broad relationships between climate and disease is realistic, then climate change may already be affecting human health.

The total current estimated burden is small relative to other major risk factors measured under the same framework. However, in contrast to many other risk factors, climate change and its associated risks are increasing rather than decreasing over time.

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