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ABSTRACT

The relationship between climate and human health is not a new concept. In fact at least as far back as Hippocrates, many believed that human health was intricately linked to the seasons, local weather patterns and other environmental factors. Recently, the role of the environmental and climate in disease dynamics has become a subject of increasing interest to clinicians, epidemiologists, microbiologists and ecologists. Scientific interest has been further stimulated by the growing problems of antibiotic resistance among pathogens, emergence and reemergence of infectious disease worldwide and the debate concerning climate change and health.

Key words: *Environmental, climate change, public health, infectious diseases.*

RESUMEN

El estudio del clima y la salud no es un concepto nuevo. En realidad esta relación la podemos ubicar en la época de Hipócrates, cuando se planteaba que el estado de la salud se relacionaba con las estaciones del año, los patrones locales de las condiciones atmosféricas y otros factores ambientales. Durante los últimos años el papel del medio ambiente y su influencia en diversas enfermedades ha sido objeto de estudio de médicos, epidemiólogos, microbiólogos y ecologistas. El interés científico de esta relación ambiente-salud se ha estimulado por el aumento en lo referente a los problemas de resistencia a antibióticos entre patógenos, la emergencia y reemergencia de enfermedades infecciosas en todo el mundo y por el debate concerniente al cambio climático y salud.

Palabras clave: Medio ambiente, cambio climático, salud pública, enfermedades infecciosas.

INTRODUCTION

Climate research has thrived within the scientific community for the past decades. To date, climate research has dealt mainly with questions about the physical dynamics of climate understood as a natural phenomenon. For the purposes of policy, accurate numerical and system-analytical answers are considered sufficient answers while the translation of such knowledge into practical decisions in the societal and political realm are taken for granted.

Part of the growing interest in the effects of climate on health is due to concerns about global climate change and variability. In 1997 and 1998 global temperatures reached their highest levels since recordkeeping began last century, 9 of the 11 hottest years in the 20th century occurred within the last 10 years. The global mean surface temperature has increased by 0.4º C in the past 25 years, and climate scientists are becoming increasingly confident that the anticipated process of global warming has begun. Three studies indicating disproportionate mid-atmospheric warming, disproportionate night-time and winter warming, and increased variability. More recent studies continue to find a dominance of greenhouse gases over solar and other influences.

CLIMATE CHANGE

Global warming is projected to increase both ambient temperatures and rainfall at high latitudes and high elevations. The migration of plants to higher altitudes has been documented on numerous peaks in the European Alps, the Sierra Nevada, Nueva Zealand and Alaska.[1] These botanical trends, indica-

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tive of warming, have accompanied other physical changes such as the retreat of montane glaciers in Argentina, Peru, Alaska, Iceland, Norway, the Swiss Alps, Kenya, the Himalayas, Indonesia and New Zealand.[2] Since 1970 the lowest level at which freezing occurs has ascended about 150 m higher in mountains in tropical latitudes (from 30 N to 30 S latitude), which is equivalent to 1º C warming.[3]

Meanwhile, there have been reports that both insects and insect-borne disease (including malaria and dengue fever) have been experienced at increasingly higher altitudes in Africa, Asia and Latin America.[4,5] Highland malaria is also reportedly increasing in Papua New Guinea and parts of sub-Saharan Africa. A number of factors may be implicated, including deforestation, population movements and breakdown in public health, and it is not yet possible to attribute these increase to climatic change. However, a climatic influence is plausible, and the emerging pattern is compatible with the botanical and physical evidence of warming at high altitudes.[6]

HEALTH EFFECTS

A change in world climate would have wide-ranging, mostly adverse, consequences for human health.[7,8] Most of the anticipated health impacts would entail increased rates of illnesses and death from familiar causes. However, the assessment of future health outcomes refers to climatic-environmental conditions not previously encountered. Such conditions, particularly in conjunction with other global environmental changes now occurring (deforestation) may also increase the likelihood of unfamiliar health outcomes, including the emergence of new infectious disease agents.[9] The 1997-1998 El Niño event brought surprises: Indonesia and Brazil experienced widespread respiratory illness due to haze from uncontrolled burning of tropical forests.[10] With Hurricane Mitch in Central America, in November 1998, deforested areas experienced increased flooding and landslides, the aftermath spawning of water, insect and rodent-borne diseases (cholera, malaria, dengue fever and leptospirosis).[11]

The potential health impacts of global warming can be broadly classified as direct or indirect *(Table 1)*. The former category refers to the direct impact of extremes in local weather conditions. Epidemiological studies and public health data have identified how thermal stresses (including heat waves) and weather disasters can result in serious illness, injuries and death. Estimating the consequences of indirect effects poses more of a challenge because those impacts typically result from changes in complex processes. They include alterations in the transmission of vector-borne infectious disease, alterations in water quality and quantity, and changes in the productivity of agroecosystems, with the potential for displacement of vulnerable populations as a result of local declines in food supply or sea level rise.[12]

Table 1. Direct and indirect potential effects on health of changes in temperature and weather.

Mediating process	*Health outcome*
Direct effects	
Changed frequency or intensity of other extreme weather events	Deaths, injuries, psychological disorders
Exposure to thermal extremes	Changed rates of illness and death related to heat and cold
Indirect effects	
Changed local ecology of water-borne and food-borne infective agents	Changed incidence of diarrheal and other infectious disease
Effect on range and activity of vectors and infective parasites	Changes in geographical ranges and incidence of vector-borne disease
Biological impact of air pollution changes (pollens and spores)	Asthma and allergies, other acute and chronic respiratory disorders and deaths

Table 2. Influence of environment, climate and weather on cholerae dynamics.

Factor	*Climate and/or weather drives*	*Influence (s)*
Temperature	Seasons, interannual variability	Growth of *V. cholerae*, blooms, infection by temperate phages
Sunlight	Seasons, monsoons, interannual variability	Survival of *V. cholerae*, phytoplankton blooms
Salinity	Seasons, monsoons, ENSO, sea level rise	Growth of *V. cholerae*, expression of cholera toxin
pH	Seasons, interannual variability, phytoplankton growth	Growth of *V. cholerae*
Exogenous products of algal growth	Seasons, monsoons, interannual variability in light, nutrients	Survival of *V. cholerae*

The range of likely health impacts can be assessed, in part, by studying the consequences of local climatic variability, including short-term trends. One useful, although limited, analogue of future climatic change is the El Niño Southern Oscillation (ENSO) cycle, which affects temperature, precipitation and extreme events (storms) in many parts of the world. The ENSO cycle influences, often strongly, the incidence of various infectious diseases in many parts of the world: malaria in northeastern Pakistan, Sri Lanka, Colombia and Venezuela, Murray Valley encephalitis and epidemic polyarthritis in Australia and dengue fever in the South Pacific.[13-18] Historical analyses showed that the risk of a malaria epidemic increased 5-fold in the semi-arid Punjab during the year following an El Niño and 4-fold in southwestern Sri Lanka during the El Niño year. El Niño events are also strongly associated with the number of people affected globally by natural disasters, particularly droughts, that cause major harm to human health.[19] A recent review has documented a range of health impacts that may be affected by the ENSO cycle.[20]

EFFECTS OF GLOBAL CLIMATE ON INFECTIOUS DISEASES

The role of the environmental and climate in disease dynamics has become a subject of increasing interest to clinicians, epidemiologists, microbiologists and ecologists. Much of the interest has been stimulated by the growing problems of antibiotic resistance among pathogens, emergence and/or reemergence of infectious diseases worldwide, the potential of bioterrorism and the debate concerning climate change. Cholera, caused by *Vibrio cholerae*, lends itself to analyses of climate in infectious disease, coupled to population dynamics of pathogenic microorganisms, for several reasons. First, the disease has a historical context linking it to specific seasons and biogeographical zones. In addition, the population dynamics of *V. cholerae* in the environment are strongly controlled by environmental factors, such as water temperature, salinity and the presence of copepods, which are, in turn, controlled by larger-scale climate variability.[21]

The spatial and temporal patterns of emerging and remerging diseases have been changing throughout history due to variety of factors. Their patterns as well as incidence or prevalence of disease are influenced by a complex interaction of direct and indirect factors. Among physical factors, temperature perhaps has the most direct and significant effects on the ecology of most bacteria. It is not any different for *V. cholerae*, because warmer temperatures in combination with elevated pH and plankton blooms can influence its attachment, growth, and multiplication in the aquatic environment, particularly in association with copepods *(Table 2)*.

Cholera is primarily a water-borne disease, and an epidemic may be enhanced by secondary transmission. Yet, it has been demonstrated that *V. cholerae* can be transmitted to humans via the environment, in drinking and cooking water, irrigation water, and shellfish. With active environmental monitoring systems using epifluorescence microscopy and molecular methods for direct detection, the presence of *V. cholerae*, *ctxAB*-carrying bacteria, and vibriophages in sewage and surface waters has been shown to precede the onset of cholera outbreaks by 1 to 4 months.[22-25] Furthermore, cholera is dose dependent, with at least 10^4 cells required for infection.[26] A single copepod may carry 10^4 to 10^6 cells of *V. cholerae*, and thus incidental ingestion of a few copepods in untreated drinking water could result in an infection. Although, *V. cholerae* can be transmitted directly in water, it also acts in a vector or host dependent manner because the presence of copepods substantially raises the dose of *V. cholerae* over that in copepod-free water. Preliminary studies show that Bangladeshi households which filter their pond water through sari cloth before drinking reduce their risk of cholerae infections by approximately 50%.[27]

Integrated mathematical models are used to estimate the likely effects of climate change on vector-borne diseases. These highly aggregated models are in the early stage of development and do not take into account local environmental and ecological circumstances.[28]

Such models project substantial increases in the transmission of malaria and dengue fever worldwide and a decrease in the transmissibility of schistosomiasis because of excessive warming of water and some regional drying.[29-31] Conditions conducive to malaria transmission, for example, are expected to increase from a doubling of atmospheric carbon dioxide. The majority of computer projection indicate some increase in malaria transmissibility in response to standard scenarios of climate change. The actual changes in the incidence of malaria and dengue fever would, of course, depend on many factors, including future patterns of social development, land use and urban growth, and the effectiveness of preventive measures such as vector control and vaccination.[32]

The growth of algae in surface waters, estuaries and coastal waters is sensitive to temperature.[33,34] About 40 of the 5000 species of marine phytoplankton (algae) can produce biotoxins, which may reach human consumers through shellfish. Warmer sea temperatures can encourage a shift in species composition of algae toward the more toxic dinoflagellates. Upsurges of toxic phytoplankton blooms in Asia are strongly correlated with the ENSO cycle.[35]

It is also apparent that algal blooms potentiate the transmission of cholerae. Electron microscopy has show that algae and the zooplankton that feed upon them provide a natural refuge for *V. cholerae*, where, under normal conditions, the bacteria exist in a noncuturable, dormant state. An increase in sea surface temperature, along with high nutrient levels (eutrophication) that stimulate algal growth and deplete oxygen, can activate the blooms and vibrios. Sea surface temperature in the Bay of Bengal is correlated with algal blooms and outbreaks of cholera in Bangladesh.[36] Climate variability and change may thus influence the introduction of cholerae into coastal populations. *V. cholerae* occur in the Gulf of Mexico and along the east coast of North America.

Climate change could also affect food production, with declines concentrated in low-latitude regions, where food insecurity often already exists, including Africa, the Middle East and India. There is a range of estimates of the risk of hunger reflecting different assumptions about future populations growth, international trade and adaptive agricultural technology. Such estimates, however, do not include the likely additional influence of extreme weather events or of increases in agricultural pests and pathogens.[12]

CONCLUSIONS

Recognizing the wide-ranging potential consequences of climate change for our health and well-being can greatly strengthen the international rationale for reducing greenhouse gas emission. The present dilemmas brought about by anthropogenic climate change are in many ways unprecedented. Knowledge about the physical nature of global climate changes in not sufficient to move comprehension to a solution of the problem.

Although there is much that in unavoidably complex and uncertain about these large-scale risks to human population health, the case for health professionals urging a health-protecting, precautionary approach that will have multiple health benefits remains clear.

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