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Climate Change and Infectious Diseases

Epidemiology of infectious diseases

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For centuries humans have known that climatic conditions affect epidemic infections—since well before the basic notion of infectious agents was understood late in the nineteenth century.

The Roman aristocracy took refuge in their hill resorts each summer to avoid malaria.
South Asians learnt early that in high summer, strongly curried foods were less prone to induce diarrhoeal diseases.
In the southern United States one of the most severe summertime outbreaks of yellow fever (viral disease transmitted by the Aedes aegypti mosquito) occurred in 1878, during one of the strongest El Niño episodes on record.
In developed countries today it is well known that recurrent influenza epidemics occur in mid-winter

The economic and human cost was enormous, with an estimated death toll of around 20000 people.

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 waysof-living.

Climate change will also affect infectious disease occurrence.

Disease classifications relevant to climate/health relationships

Several different schemes allow specialists to classify infectious diseases:

For clinicians who are concerned with treatment of infected patients, the clinical manifestation of the disease is of primary importance. Alternatively,

microbiologists tend to classify infectious diseases by the defining characteristics of the microorganisms, such as viral or bacterial.

For epidemiologists the two characteristics of foremost importance are:

* the method of transmission of the pathogen and

* its natural reservoir, since they are concerned primarily with controlling the spread of disease and preventing future outbreaks.

Disease classifications relevant to climate/health relationships

Climate variability's effect on infectious diseases is determined largely by the unique transmission cycle of each pathogen.

Transmission cycles that require a vector or non-human host are more susceptible to external environmental influences than those diseases which include only the pathogen and human.

Important environmental factors include temperature, precipitation and humidity
Several possible transmission components include pathogen (viral, bacterial, etc.), vector (mosquito, snail, etc.), non-biological physical vehicle (water, soil, etc.), non-human reservoir (mice, deer, etc.) and human host.

Disease classifications relevant to climate/health relationships

Epidemiologists classify infectious diseases broadly as: anthroponoses or zoonoses, depending on the natural reservoir of the pathogen;

and direct or indirect, depending on the mode of transmission of the pathogen.

Temperature effects on selected vectors and vector-borne pathogens

Vector

* survival can decrease or increase depending on species;
• some vectors have higher survival at higher latitudes and altitudes with higher temperatures;
• changes in the susceptibility of vectors to some pathogens e.g. higher temperatures reduce size of some vectors but reduce activity of others;
• changes in the rate of vector population growth;
• changes in feeding rate and host contact (may alter survival rate);
• changes in seasonality of populations.

Pathogen

* decreased extrinsic incubation period of pathogen in vector at higher temperatures
• changes in transmission season
• changes in distribution
• decreased viral replication.

Effects of changes in precipitation on selected vector-borne pathogens

Vector

- increased rain may increase larval habitat and vector population size by creating new habitat
- excess rain or snowpack can eliminate habitat by flooding, decreasing vector population
- low rainfall can create habitat by causing rivers to dry into pools (dry season malaria)
- decreased rain can increase container-breeding mosquitoes by forcing increased water storage
- epic rainfall events can synchronize vector host-seeking and virus transmission
- increased humidity increases vector survival; decreased humidity decreases vector survival.

Pathogen

Few direct effects but some data on humidity effects on malarial parasite development in the anopheline mosquito host.

Vertebrate host

- increased rain can increase vegetation, food availability, and population size
- increased rain can cause flooding: decreases population size but increases human contact.

El Niño and malaria

Malaria is the world’s most important vector-borne disease.

Over 2.5 billion people are at risk, and there are estimated to be 0.5 billion cases and more than 1 million deaths from malaria per year.

Malaria incidence is influenced by: * the effectiveness of public health infrastructure, * insecticide and drug resistance, * human population growth, * immunity, * travel, * land-use change and * climate factors.

Very high temperatures are lethal to the mosquito and the parasite.

El Niño and malaria

There is a well-studied relationship between rainfall and diseases spread by insect vectors which breed in water, and are therefore dependent on surface water availability.

The main species of interest are **mosquitoes**, which spread malaria and viral diseases such as dengue and yellow fever. Mosquitoes need access to stagnant water in order to breed—conditions that may be favoured by both wet and dry conditions.

For example, heavy rain can create as well as wash away breeding sites, while in normally wet regions drought conditions can increase breeding sites by causing stagnation of water in rivers. The timing of rainfall in the year and the co-variation of other climate factors also are likely to be important.

Vector-borne disease transmission is sensitive to temperature fluctuations also. Increases in temperature reduce the time taken for vector populations to breed. Increases in temperature also decrease the incubation period of the pathogen (e.g. malaria parasite, dengue or yellow fever virus) meaning that vectors become infectious more quickly.

Warmer temperatures tend to increase biting behaviour of the vector and produce smaller adults which may require multiple blood meals in order to reproduce.

Impact of climate extremes on malaria in Irian Jaya

Beginning in late August 1997, a significant increase of unexplained deaths was reported from the central highland district of Jayawijaya.
The alarming number of fatalities rapidly escalated into September, dropping off precipitously by late October.
More than 550 deaths due to "drought-related" disease had been officially reported from the district during this 10-week period. The outbreaks occurred in extremely remote areas of steep mountainous terrain inhabited by shifting agriculturist populations.

Microscopic evidence and site survey data implicated **malaria as the principal cause** of the excess morbidity and mortality at elevations between approximately 1000 and 2200m.
The dramatic increase in malaria and associated deaths was related indirectly to the prolonged and severe drought created **by the prevailing 1997–98 El Niño affecting the Australasian region**.
Clinical cases of malaria were described as severe, due in large part to the low level of naturally acquired immunity in these highland populations and the predominance of Plasmodium falciparum infection. Disease may have been further exacerbated by the population's compromised nutritional status because of drought-related severe shortages of staple foods.

Impact of climate extremes on malaria in Irian Jaya

Based on a retrospective investigation, an a posteriori epidemiological explanation of the probable interrelated causes of the epidemic is presented:

"Beginning in late July 1997, drought conditions resulted in numerous transient pools of standing water along zones of steep gradient streams normally associated with fast-flowing water.

This permitted sufficient and rapid increases in vector populations (Anopheles punctulatus complex) that could sustain recently introduced or intensified local low-level malaria transmission. Moreover, water and food shortages contributed to increased demographic movement and exposure to high risk malaria endemic lowlands, thus increasing the prevalence of human infections and infectious reservoirs in those populations returning to the highlands."

Dengue

Dengue is the most important arboviral disease of humans, occurring in tropical and subtropical regions worldwide.

In recent decades, dengue has become an increasing urban health problem in tropical countries.

The disease is thought to have spread mainly as a result of ineffective vector and disease surveillance;

- inadequate public health infrastructure;
- population growth;
- unplanned and uncontrolled urbanization;
- and increased travel.

The main vector of dengue is the domesticated mosquito, Aedes aegypti, that breeds in urban environments in artificial containers that hold water. Dengue also can be transmitted by Aedes albopictus, which can tolerate colder temperatures.

Rodent-borne diseases

Rodents act as reservoirs for a number of diseases whether as intermediate infected hosts or as hosts for arthropod vectors such as ticks.

Certain rodentborne diseases are associated with flooding including leptospirosis, tularaemia and viral haemorrhagic diseases.

Other diseases associated with rodents and ticks include plague, Lyme disease, tick borne encephalitis (TBE) and hantavirus pulmonary syndrome (HPS).

Rodent populations have been shown to increase in temperate regions following mild wet winters. One study found that human plague cases in New Mexico occurred more frequently following winter-spring periods with aboveaverage precipitation. These conditions may increase food sources for rodents and promote breeding of flea populations. Ticks also are climate sensitive

Rodent-borne diseases

Infection by hantaviruses mainly occurs from inhalation of airborne particles from rodent excreta. The emergence of the disease hantavirus pulmonary syndrome in the early 1990s in the southern United States has been linked to changes in local rodent density.
Drought conditions had reduced populations of the rodents' natural predators; subsequent high rainfall increased food availability in the form of insects and nuts.
These combined effects lead to a tenfold increase in the population of deer mice from 1992 to 1993. In 1998, an increase in cases of hantavirus was linked to increased rodent populations which, in turn, were attributed to two wet, relatively warm winters in the southern United States associated with 1997/98 El Niño. A comprehensive study by Engelthaler et al. in the Four Corners region, USA, concluded that aboveaverage precipitation during the winter and spring of 1992–1993 may have increased rodent populations and thereby increased contact between rodents and humans and viral transmission.

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Diarrhoeal illness

Many enteric diseases show a seasonal pattern, suggesting sensitivity to climate.

In the tropics diarrhoeal diseases typically peak during the rainy season.

Floods and droughts are each associated with an increased risk of diarrhoeal diseases, although much of the evidence for this is anecdotal.

The suggestion is plausible, however, since heavy rainfall can wash contaminants into water supplies, while drought conditions can reduce the availability of fresh water leading to an increase in hygiene-related diseases.

Diarrhoeal illness

Major causes of diarrhoea linked to contaminated water supplies are: cholera, cryptosporidium, E.coli, giardia, shigella, typhoid, and viruses such as hepatitis A.

Outbreaks of cryptosporidiosis, giardia, leptospirosis and other infections have been shown to be associated with heavy rainfall events in countries with a regulated public water supply.

Transmission of enteric diseases may be increased by high temperatures, via a direct effect on the growth of disease organisms in the environment.

In 1997 a markedly greater number of patients with diarrhoea and dehydration were admitted to a rehydration unit in Lima, Peru, when temperatures were higher than normal during an El Niño event.

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Cholera

Traditionally cholera is viewed as a strictly faecal–oral infection but increased attention is being paid to the environmental determinants of this disease.

The discovery of a marine reservoir of the cholera pathogen and its long term persistence with various marine organisms (in the mucilaginous sheath of blue-green algae and copepods) helps to explain the endemicity in certain regions, such as the estuaries of the Ganges and Bramaputra in Bangladesh.

Recent work has suggested links between the seasonality of cholera epidemics and seasonality of plankton (algal blooms) and the marine food chain. A study of Vibrio cholerae 01 in Bangladesh (1987–90) found that abundance increases with the abundance of copepods (which feed on phytoplankton) in coastal waters. Analysis of cholera data from Bangladesh showed that the temporal variability of cholera exhibits an interannual component at the dominant frequency of El Niño.

Several cholera outbreaks occurred in 1997 following heavy rains. Countries in East Africa were severely affected: major cholera outbreaks occurred in the United Republic of Tanzania, Kenya, Guinea-Bissau, Chad and Somalia.

Outbreaks also were reported in Peru, Nicaragua and Honduras.

However, the total number of cholera cases reported to WHO in 1997, globally and by region, was similar to that in 1996. Countries that experienced increased cholera incidents in 1997 are at risk of increases in cholera in subsequent years. In 1997, the regional WHO cholera surveillance team was aware of the forecasts of an El Niño-related drought in south-east Africa.

The team was able to institute measures to help reduce the severity of a cholera outbreak in Mozambique by increased monitoring and heightened preparedness of health care institutions.

Conclusion

Are the evidence linking climatic factors such as temperature, precipitation, and sea level rise, to the lifecycles of infectious diseases, including both direct and indirect associations via ecological processes. Many studies demonstrate seasonal fluctuations in infectious diseases but few have documented long-term trends in climate-disease associations.

Gaps in knowledge indicate that future initiatives are required in the following areas:

* Increase in active global disease surveillance.
* Continuation of epidemiological research into associations between climatic factors and infectious diseases.
* Further development of comprehensive models.
* Improvements in public health infrastructure.