Coming to a Boil: Climate change encourages the expansion of infectious disease

Author: R. John Davenport
February 1, 2008

Will there be a triumphant progress of infection diseases while heating up our climate?

“Whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the seasons of the year, and what effects each of them produces for they are not at all alike, but differ much from themselves in regard to their changes. Then the winds, the hot and the cold, especially such as are common to all countries, and then such as are peculiar to each locality. We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualities.”

An evening in the area of the former Larsen-B-Iceshelf and the Antarctic peninsula. © Gauthier Chapelle, AWI

So wrote the Greek physician Hippocrates in 400 BC, imploring physicians to heed the effects of weather and climate on disease. Now, as global climate change threatens to alter life as we know it, the effect of climate on health, including infectious diseases, returns to the fore. Some evidence suggests that climate has already exacted a toll on the human population by spurring disease outbreaks and spreading the disease to new areas. But the full extent of the impact on infectious diseases remains to be understood. Scientists need more knowledge in order to predict outbreaks and prepare populations at risk, and to understand how climate-correcting measures, such as reducing fossil fuel consumption and greenhouse gas emissions, are for improving human health.

Scientists, and to an increasing degree, the general public, agree that the earth's climate is changing and that humans have played a significant role in those changes. CO2 levels in the atmosphere have soared 30% since the industrial revolution, and the earth’s temperature has risen by 0.3 degrees Celsius over the last 30 years. The Intergovernmental Panel on Climate Change (IPCC), in its 3rd assessment in 2001, estimated that the temperature would rise another 1.4 to 5.4 degrees Celsius by the end of the century. The IPCC also reported with high confidence that this temperature rise was due in significant measure to human activities—primarily consumption of fossil fuels. As the air temperature rises, sea temperatures also rise, and glaciers and polar ice melt. In a positive feedback loop, these effects lead to even faster warming: warmer seas become more acidic and absorb less CO2, and land lacking snow and ice absorbs solar radiation, rather than reflects it.

In the Hollywood view, rising sea levels flood land and turn inland villages into beachfront real estate. Flooding directly from rising seas is a genuine concern: water levels could rise by 30 - 90 cm (1-3 feet) by 2100. But an increase in the frequency and severity of storms could be a greater worry. An increase in the amount of water vapor in the atmosphere would lead to more intense downpours, while changing weather patterns would leave certain parts of the globe parched. Already, El Niño and La Niña events—periodic changes in pacific ocean events that dramatically change sea surface temperatures and alter rainfall patterns—have become more frequent in the last 30 years.

Aside from presenting immediate harm to people—people can drown as a result of flooding or die of starvation or dehydration from drought—these changes also threaten to alter patterns of infectious disease for the worse. Recent reports have highlighted the potential risks: for instance, the IPCC's 2007 fourth assessment and the 2005 Climate Change Futures report—a joint venture between the Harvard Center for Health and Global Environment, Swiss Re, a Zurich-based reinsurance company, and the United Nations Development Programme—addressed the impact of climate change on health. Climate change will likely alter where disease vectors roam, and therefore where the diseases they carry strike. It will also likely increase the number of people who perish from water-borne infections, such as cholera and cryptosporidiosis. And climate change is already exacting a toll on animals, wiping out species of amphibians, and threatening food supplies by harming important links in the food chain such as oysters.

It's in the Water

Infectious diseases carried by vectors such as mosquitoes or ticks are among the most sensitive to temperature, so they have been studied most intensely with respect to climate change. These diseases also represent significant risks to human health. Malaria, for instance, threatens 40% of the world's population. As many as 0.5 billion new cases occur each year, and perhaps 1 million people die annually.

Those numbers may expand with climate change. As temperatures warm, mosquitoes, *Anopheles*, reproduce more often and bite people more frequently. In addition, the malaria parasite, *Plasmodium*, residing in mosquitoes matures more quickly. At 20 degrees C (68 degrees F), the parasite develops in 26 days. But at 25 degrees C (77 degrees F), it only requires 13 days. Because malaria-carrying mosquitoes only live for a few weeks, increasing the parasite maturation rate by a few days could substantially increase how frequently mosquitoes infect people with the parasite.

Climate change is also pushing malaria into new areas. Warming temperatures mean that malaria mosquitoes can survive at higher elevations, so mosquitoes are moving to higher elevations where malaria wasn't previously a problem, such as highland areas of eastern Africa. And malaria is already cropping up again in parts of the world where public health efforts had previously eradicated the disease, such as the United States, the Soviet Union, the Korean Peninsula, southern Europe, and the coast of South Africa.

Warming isn't the only contribution of climate to the spread of malaria. Droughts can force inhabitants of a malaria-free region to seek refuge in moister, more malaria-prone areas; they can

carry malaria back to their original home when drought subsides. And although mosquitoes can't survive droughts, more moderate droughts can reduce the number of animals that eat mosquitoes. On the flip side, increased rainfall can cause people and mosquitoes to converge on the same limited number of water sources.

Scientists have observed an increase in malaria in the East African highlands, but some controversy remains about the degree to which climate change is to blame. Researchers must mesh together public health records and climate data to tease apart the effects of climate from those caused by movement of people into and out of particular geographic areas, malaria abatement programs, development of resistance to malaria drugs or pesticides, or changes in land use. For instance, deforested areas flood easily and create mosquito breeding grounds; deforestation also reduces habitat for mosquito predators. Nevertheless, a recent analysis suggests a strong connection between warming temperatures and malaria increase in the African highlands. And overall, some predictions suggest a dramatic effect on malaria worldwide. By 2100, 50% more of the worlds population will be at risk for malaria, according to some models by Paul Epstein, Harvard.

Other vector-borne diseases also run the risk of spreading as climate changes. Dengue fever, the most deadly viral disease, also spreads more rapidly as temperature rises; similar to malaria-carrying mosquitoes, those that carry dengue also mature more quickly as the environment warms. Some estimates predict that 5 to 6 billion people will be at risk for dengue by 2100 based on current climate predictions, compared with 3.5 billion if no climate alterations occurred.

And Lyme disease also appears to be spreading as the climate changes. First described in 1977, Lyme disease is the most common vector-borne disease in the United States; it is also common in Europe. Ticks carry the organism responsible for Lyme diseases; this arthropods also carry other diseases such as babesiosis. Antibiotics cure Lyme disease in most cases. But some people experience chronic Lyme infections, and experience devastating symptoms such as joint pain, headache, and neurological problems.

Lyme disease is spreading throughout the northeast and Atlantic states of the United States, and some predictions suggest it could expand even farther north into Canada. With warming temperatures and increased rainfall, ticks are rising in number and are present for more months of the year. The disease is not only spreading to new areas, but also becoming more common in those areas where it already exists. The effects of climate are also compounded as people encroach to a greater degree on forested areas, and they and their pets have increasing contact with ticks. In Europe, disease-carrying ticks are also expanding. For instance, the tick species *Ixodes ricinus* is moving to higher elevations and more northerly latitudes in Sweden; and tick-borne infections such as encephalitis are rising and spreading in Denmark.

Cholera in the Time of Climate Change

Climate change is exacting profound effects on water supplies and those influences are altering patterns of water-borne diseases. Over 2 million people die each year from diarrheal diseases, caused in large part by unsafe drinking water and unsanitary conditions. The World Health Organization estimates that 80% of worldwide disease stems from poor sanitation and tainted water supplies.

Climate change throws multiple punches that encourage water-linked diseases. Flooding escalates, and diarrheal diseases often soar after floods. For instance, documented increases in cholera, cryptosporidiosis, and typhoid fever have occurred after floods, especially in more impoverished countries. For instance, floods during 2000 and 2001 killed 447 people in Mozambique, in addition to the several thousand who died directly because of the flood. And researchers have documented increased outbreaks of cholera in connection with rising rainfall due to El Niño events. As climate change makes El Niño events more common, cholera might rise.

At the same time drought means that water-borne microbes become more concentrated in fewer water sources. For instance, certain cholera outbreaks in the Amazon are connected with low rivers during the dry season, which creates isolated pools that accrue microbes.

In part, climate change might simply make it more likely for humans to encounter disease-causing microbes, such as cholera-triggering *Vibrio cholerae*. But climate change might also disrupt specific temperature-sensitive biological mechanisms that prevent the bugs from proliferating. For instance, researchers have found in laboratory studies that elevated temperatures prevent certain bacteria from making an antibiotic compound that kills *Vibrio cholerae*--these bacteria compete with *Vibrio* to colonize organic matter floating in water. Such effects might further encourage the spread of cholera as temperatures warm.

All in it Together

Climate change is not only encouraging the spread of human diseases, but also diseases of animals that are closely connected with human survival. For instance, blooms of algae are becoming more frequent and intense, and lasting longer. These blooms can directly sicken humans who ingest toxins produced by the organisms. Blooms can also harm important aquatic organisms in the food chain; they can lead to dead zones in bays and estuaries that decimate beds of sea grass and remove important habitats that nurture shellfish.

Oysters appear to be suffering substantially from climate change. Oyster populations in the Atlantic ocean on the United States' east coast have declined dramatically over the last 4 decades, in large part due to two infectious diseases, Dermo and MSX, short for multinucleated sphere unknown, its name before the cause, *Haplosporidium nelsoni*, was discovered. Dermo is a warm water protozoan pathogen, so increasing sea surface temperatures have encouraged the spread of the diseases. Dermo is now found in Delaware Bay, in the central Atlantic coast, but also further north, in Long Island Sound, Massachusetts, and Rhode Island. It is also found in the northernmost reaches of the U.S. Atlantic coast, in Maine, and is spreading to Maine. Milder winters have enabled the parasite responsible to survive throughout the year, as well as spread to more

distant habitats. And warmer waters and increased salinity has fostered the spread of *Haplosporidium nelsoni* (MSX).

Oysters are an important fishery stock, but also keep the marine environment healthy. By filter feeding, oysters temper the quantities of nutrients and microorganisms in coastal waters. Without the oysters' contribution, algae proliferate and poison the waters, creating dead zones where fish and shellfish can't live.

Amphibians are also succumbing to infectious diseases that proliferate during climate change. For instance, harlequin frogs endemic in Central America have disappeared at an alarming rate, in large degree due to a fungus that infects and kills the animals. Some researchers posited a connection to climate change, and a recent analysis suggests that climate change makes the jungle more hospitable for the fungus. Climate change has elevated night time temperatures, and brought more clouds during the day. The night time temperature is moving closer to the optimum temperature for the fungus, and the change in cloud cover provides fewer hot spots for frogs to seek refuge from the fungus. While not of direct consequence to human health, the disappearance of frogs points to the devastating effect that a changing climate has on biodiversity and may remove important links – such as the oyster – in a health environment.

Researchers will work on to understand the effect of climate change on not only the health of the planet but also that of its inhabitants, and could provide tools to predict when and where infectious outbreaks occur. No matter how well we understand and predict climate-triggered outbreaks, it appears clear that mitigating climate change – reducing greenhouse gas emissions, in particular – is the most important step towards stemming the spread of infectious diseases.