# Global Climate Change and Infectious Diseases

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The 2009 United Nations Climate Change Conference in Copenhagen ended on December 18 without passage of a binding resolution for tackling global climate change. With the debate over U.S. health care reform raging, this event went largely unnoticed by the U.S. health care community. However, climate change will have enormous implications for human health, especially for the burden of vectorborne and waterborne infectious diseases.

Climate change is occurring as a result of an imbalance between incoming and outgoing radiation in the atmosphere.[1] As solar radiation enters the atmosphere, some of it is absorbed by the earth's surface and reemitted as infrared radiation, which is then absorbed by greenhouse gases — primarily carbon dioxide, methane, and nitrous oxide — which result from the combustion of fossil fuels and which cannot be effectively removed from the atmosphere because of deforestation. This process generates heat. As the concentrations of greenhouse gases in the atmosphere have reached record levels, global temperatures have risen at a faster rate than at any time since records began to be kept in the 1850s, and temperatures are expected to increase by another 1.8 to 5.8°C by the end of this century. The hydrologic cycle will be altered, since warmer air can retain more moisture than cooler air. Some geographic areas will have more rainfall, and some more drought, and severe weather events — including heat waves and storms — are expected to become more common. For these reasons, the term "climate change" is now preferred over the term "global warming." Because of rising temperatures and changing rainfall patterns, climate change is expected to have a substantial effect on the burden of infectious diseases that are transmitted by insect vectors and through contaminated water.

Insect vectors tend to be more active at higher temperatures. For example, tropical mosquitoes such as anopheles species, which transmit malaria, require temperatures above 16°C to complete their life cycles.[2] Some vectorborne diseases such as malaria are also thought of as water-vectored diseases, since mosquitoes typically thrive in aquatic habitats, where they lay their eggs in water-filled containers. Thus, epidemics of malaria tend to occur during rainy seasons in the tropics. In contrast, epidemics of the mosquito-borne West Nile virus infection can occur during times of drought. This happens because mosquitoes and birds (the primary hosts of the virus) are brought into proximity at scarce water sources, enhancing the transmission of the virus. In addition, the populations of the natural predators of mosquitoes are greatly reduced during times of drought, as wetlands dry up.

Like vectorborne diseases, waterborne infectious diseases are also strongly affected by climate. During times of drought, water scarcity results in poor sanitation, and much of the population can be exposed to potentially contaminated water. For example, there is currently an epidemic of cholera in northern Kenya in the wake of a severe drought. Like drought, excess rainfall and flooding can also contribute to epidemics of waterborne infectious diseases, in this case due to poor sanitation resulting from runoff from overwhelmed sewage lines or the contamination of water by livestock. An example is the 1993 epidemic of diarrheal disease due to cryptosporidium in Milwaukee after heavy spring rains[3] — or the typical seasonality of bacterial and protozoal diarrheal illnesses.

There are some widely cited examples suggesting that climate change has already resulted in the introduction of certain infectious diseases into previously unaffected geographic areas. One such example is the spread of malaria into highland regions of East Africa, where this disease previously

did not exist.[2] This spread occurred in the setting of weather that was much warmer and wetter than usual; it resulted in high rates of illness and death, because the disease was introduced into a largely nonimmune population.

To describe the effect of climate change on a more global scale, the World Health Organization (WHO) has released data regarding the estimated effects on human health as of the year 2000 (see table).[4] What is readily apparent from these data is that developing regions of the world have been disproportionately affected by climate change relative to developed regions. This imbalance stands in stark contrast to the imbalance in greenhouse-gas emissions, which are almost entirely attributable to developed countries, such as the United States, and countries with rapidly developing

The WHO report also includes estimates of the future global burden of disease that will result from climate change.[4] It is predicted that by 2030 there will be 10% more diarrheal disease than there would have been with no climate change and that it will primarily affect the health of young children; indeed, the impact on children might well be amplified by the effects of such diseases on malnutrition, development, and cognition. If global temperatures increase by 2 to 3°C, as expected, it is estimated that the population at risk for malaria will increase by 3 to 5%, which means that millions of additional people would probably become infected with malaria each year.

In an attempt to halt climate change, international efforts to reduce emissions have already been put in place. The Kyoto Protocol has now been ratified by 187 nations (but most notably not by the United States) and went into effect in 2005. The purpose of the recent meeting in Copenhagen was to establish a framework for tackling climate change beyond 2012, when the Kyoto Protocol expires. In the end, no binding resolution was passed. Rather, several countries (including the United States) developed a nonbinding agreement to halt the increase in global temperature at 2°C, with no mention of targets for emissions. One of the major sticking points at the conference was the question of the responsibility that developed countries have to assist developing countries (including China and India) in reducing emissions, and the United States ultimately did pledge financial assistance to help poor countries deal with climate change. On a national level, the American Clean Energy and Security Act (Waxman–Markey bill), which sets limits on emissions through a cap-and-trade system (in which companies that produce fewer emissions than the cap allows receive credits that may be sold to heavier polluters), was passed by the House of Representatives in June 2009 but still awaits a vote in the Senate.

Although governments must take the lead in tackling climate change, I believe that it is also our responsibility as members of the health care community to do our part. Recommendations for ways in which individuals and businesses can reduce their greenhouse-gas emissions are available from the Environmental Protection Agency.[5] In addition, though reducing emissions is of the utmost importance, we must remember that the best-case scenario would be a global temperature increase of about 2°C. Therefore, we must also focus our efforts on mitigating the effects of climate change, including its potential impact on the global burden of infectious diseases. Additional research is needed on the ecology and epidemiology of infectious diseases that will probably be affected by climate change. The best means for accomplishing this aim would be to incorporate research on the effect of climate change into existing infrastructures, such as the ambitious malaria-eradication program recently launched by the Bill and Melinda Gates Foundation. One of the goals of research on climate change should be the development of early warning systems to help populations prepare for impending epidemics. As we move forward, it is imperative that organizations such as the WHO continue their missions of treating and preventing otherwise neglected infectious diseases, as part of a multifaceted approach to improving global health. Effective treatments and vaccines will go a long way in preventing human suffering that could otherwise occur as a result of climate change.

Disclosure forms provided by the author are available with the full text of this article at NEJM.org.

## Source Information

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