GLOBAL WARMING

If the Mercury Soars, So May Health Hazards

Two years ago, three top environmental scientists put forward a startling suggestion: El Niño may have helped promote a deadly cholera outbreak in South America in 1991. According to microbiologist Rita Colwell, president of the Maryland Biotechnology Institute, Harvard University tropical medicine professor Paul Epstein, and Harvard biologist Timothy Ford, El Niño conditions—a cyclical warming of the tropical Pacific Ocean that affects global climate—stimulated growth of plankton that harbor the cholera bacterium, leading to thousands of deaths in 19 Latin American countries (*The Lancet*, vol. 342, p. 1216). Although their theory is controversial, the idea has gained considerable support. Indeed, a growing number of researchers believe that the cholera outbreak could be a harbinger of the kinds of health hazards that might result from long-term climate changes triggered by global warming.

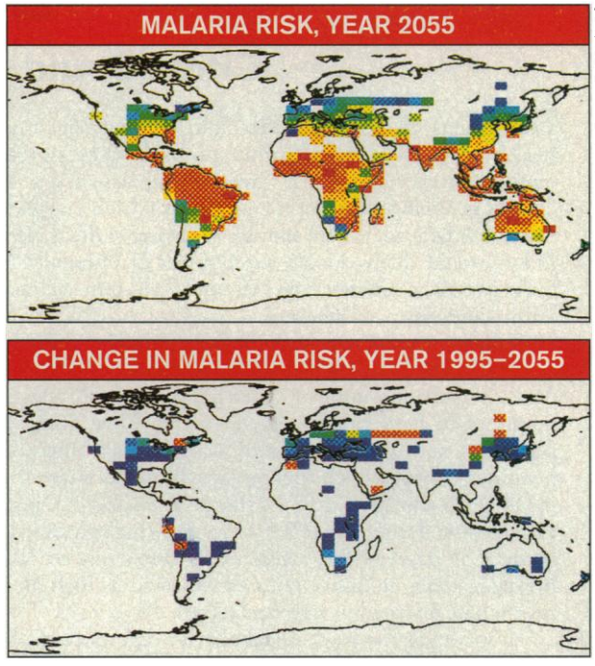
Until now, concern about the potential effects of global warming—temperature increases that may occur years from now as a consequence of industrial emissions of carbon dioxide and other "greenhouse" gases—has centered largely on the physical havoc it might wreak, such as rising sea levels flooding low-lying areas and more frequent violent storms. But there are growing indications that the potential effects of global warming on human health are no less serious. Global climate models point to the possibility of hundreds of thousands of additional deaths each year from a rising incidence of heat waves (see box on p. 958) and tens of millions more cases of infectious diseases as mosquitoes and other pests expand their ranges. "The health effects have been a curious blind spot" in global warming studies, says Tony McMichael, an epidemiologist at the London School of Hygiene and Tropical Medicine. However, he warns, "once you start destabilizing large-scale natural systems, you are actually tinkering with the very foundations of life support."

These possible health effects are about to get more attention. The World Health Organization (WHO) plans to issue a major report on the subject later this year, and the Intergovernmental Panel on Climate Change (IPCC), in a forthcoming update of a landmark 1990 study on climate change, will include for the first time a chapter on the health impacts of climate change. In addition, this spring the White House will sponsor a conference on health and climate change. "This is an emerging field and a genuine issue to which we should be giving some really serious attention," says Robert Watson, associate director for the environment at the White House Office of Science and Technology Policy and co-chair of an IPCC working group on the effects of global warming.

Global warming is expected to deliver its most deadly punch in the developing world, say epidemiologists, whose models predict an increased prevalence of diseases such as malaria, schistosomiasis, sleeping sickness, dengue, and yellow fever. Each year these diseases afflict more than 600 million people, killing more than 2 million (see table). Some scientists predict global warming could tack on hundreds of thousands of deaths a year.

"The spread of infectious diseases will be the most important public health problem related to climate change," says Jonathan Patz, a Johns Hopkins microbiologist who is working on the issue at the U.S. Environmental Protection Agency. Even a modest global temperature increase is expected to extend the range of the vectors—the mosquitoes, flies, and snails—that transmit these diseases. "You're dealing with cold-blooded insects that respond to subtle changes in temperatures," Patz says.

Data on recent warming trends support this observation. For instance, ecologist Michael Loevinsohn of the International Development Research Centre in New Delhi, India, has linked a 1-degree-Celsius increase in the average temperature in Rwanda in 1987 to a 337% rise in the incidence of malaria that year. Especially vulnerable were mountainous areas of Rwanda in which malaria had been "rare or absent," according to Loevinsohn's findings, published last year in *The Lancet* (vol. 343, p. 714). Loevinsohn's data coincide with several recent studies showing that one of the prime carriers of dengue and yellow fever—the *Aedes aegypti* mosquito—has extended its range "higher into the mountains than ever



PIM MARTENS/NAT. INSTITUTE OF PUBLIC HEALTH AND ENVIRONMENTAL PROTECTION, THE NETHERLANDS

Warming and malaria. Computer model predicts the potential spread of the most virulent malaria parasite, *Plasmodium falciparum*, with global warming of up to 5 degrees Celsius. Darker areas indicate elevated risk.

MAJOR TROPICAL DISEASES LIKELY TO SPREAD WITH GLOBAL WARMING

Disease	Vector	Population at risk (millions)	Prevalence of infection	Present distribution	Likelihood of altered distribution with warming*
Malaria	mosquito	2100	270 million	(sub)tropics	+++
Schistosomiasis	water snail	600	200 million	(sub)tropics	++
Filariasis	mosquito	900	90 million	(sub)tropics	+
Onchocerciasis (river blindness)	black fly	90	18 million	Africa/Latin America	+
African trypanosomiasis (sleeping sickness)	tsetse fly	50	25,000 new cases/year	tropical Africa	+
Dengue	mosquito	estimates unavailable		tropics	++
Yellow fever	mosquito	estimates unavailable		tropical South America and Africa	+

SOURCES: WORLD HEALTH ORGANIZATION; *THE LANCET*
*As assessed by WHO: + = likely, ++ = very likely, +++ = highly likely

Cities Could Face Killer Heat Waves

For citizens of industrialized countries, the biggest potential health hazard from global warming is likely to be an increase in mortality from summer heat waves. An increase of 2 to 4 degrees Celsius in average summer temperatures, which one widely used model predicts, may seem a minor tweaking of the thermometer. But it would likely double the number of unusually hot days during a typical summer, says Laurence Kalkstein, a climatologist at the University of Delaware.

Kalkstein and climatology Ph.D. student Karen Smoyer, now at the University of Minnesota, have developed a model to predict how global warming–induced hot spells would affect summer mortality in large urban centers such as New York, Toronto, Shanghai, and Cairo. It's based on looking at "threshold" temperatures beyond which the mortality rate escalates rapidly. For instance, the researchers found that an average of 100 people died in Shanghai during the 1980s when daily highs reached a maximum of 34 degrees. But when temperatures rose to 38 degrees, however, daily mortality rates escalated to as high as 300, the researchers reported in *Experientia* (vol. 49, p. 969).

How could a few degrees make such a difference in Shanghai? The scientists calculated a 50% increase in the prevalence of two air masses—one characterized by hot, clear, and high atmospheric pressure conditions, the other by hot, cloudy, and low-pressure conditions—that account for most of the fatalities.

When Kalkstein and Smoyer plugged these observations into their global warming model, which predicted a global temperature rise of 2 to 4 degrees, they found that the mortality rate in New York City would increase from 320 heat-related deaths per summer (the highest in the United States) to at least 880. Los Angeles would increase from 84 to 824; Chicago, from 173 to 622; Montreal, from 69 to 218; and Cairo, from 281 to 1125. In addition, Kalkstein says, the higher temperatures would exacerbate respiratory ailments such as asthma and bronchitis.

Kalkstein acknowledges that mitigating factors such as air conditioning might lower the mortality rate by 25% to 30%, but only in industrialized countries. "We have to realize it will be very unlikely to have air-conditioning as a mitigating factor in Cairo and Shanghai," Kalkstein says. Likewise, the model predicts that slightly warmer winters will not appreciably reduce mortality rates. That's because most winter-related deaths—from flu and other infectious diseases—are caused by the sustained effects of low temperatures, which keep people indoors, rather than a sudden plunge in the mercury.

–R.S.

before" in such diverse regions as Costa Rica, Colombia, India, and Kenya, Epstein says.

Researchers have also linked short-term climate variations, including warm spells and heavy rains, from El Niño to outbreaks of illness and infectious disease. Besides cholera in Latin America, Epstein and Colwell point to data suggesting a similar link between El Niño and recent cholera outbreaks in Bangladesh. An outbreak of hantavirus respiratory illness in the Southwestern United States that killed 27 people in 1993 has also been indirectly tied to El Niño. The outbreak is believed to have been caused by an explosion in the deer mouse population following heavy rains from an El Niño warming that led to a jump in the animal's food supply. And these aren't passing concerns: Recent data suggest that warming in the deep oceans may be driving El Niño conditions, which have occurred more frequently and persisted longer than usual since 1980.

Spurred by these warning signals, scientists worldwide are now trying to model how diseases will spread if temperatures rise in the next century. A research team led by environmental scientist Pim Martens of the National Institute of Public Health and Environmental Protection in Bilthoven, the Netherlands, has devised a computer model of malaria infections based on an extended range of malaria-carrying mosquitoes. The results, in press in *Environmental Health Perspectives*, indicate that an average global temperature increase of 3 degrees in the next century could increase the range of malaria-carrying mosquitoes and result in 50 million to 80 million new malaria cases per year (see maps). "As far as trying to predict something so far into the future, this is an excellent model," says Patz.

However, researchers caution that such long-term predictions are shaky. Current projections on global warming over the next several decades range from 1.5 to 4.5 degrees, with 2.5 degrees seen as the most likely. The models also rely on several assumptions: "These are 'if, if, if, and then' questions we're asking," says McMichael.

For instance, a research team led by Epstein recently found that malaria incidence in Honduras shifted in a way that the climate models would probably not have predicted. Reporting in *The Lancet* (vol. 342, p. 1400), Epstein's team found that southern Honduras experienced twin environmental insults: erosion from grazing and farming coupled with an increase of nearly 7 degrees in average annual temperature between 1972 and 1990. Although the sharp rise in temperature killed off many malaria-carrying mosquitoes in southern Honduras, the ensuing semi-desertification in that region drove many Hondurans into recently deforested regions in the north. Subsequently, heavy rains led to an upsurge of malaria in northern Honduras that fueled an increase in cases countrywide from 20,000 in 1987 to 90,000 in 1993.

Public health programs can mitigate the potential effects of an increase in malaria transmissibility, says McMichael. For instance, although the mosquitoes that transmit malaria and dengue would be expected to migrate from Central America into the United States under many global warming scenarios, U.S. surveillance and mosquito abatement programs should retard much of the malaria threat to the U.S. population. But McMichael warns that such defenses are not foolproof. "At some stage, if pressures were to keep building up, it would be impossible to hold the line," he says. And it would be even harder to hold the line in developing countries, which have fewer resources to devote to disease surveillance programs.

One way to reduce global warming's health threat, scientists say, is to beef up global surveillance of infectious diseases. "Even if outbreaks today are not precursors of bigger things to come under the potential impact of climate change, then at least monitoring and studying them will help us better understand the interaction of climate, the environment, and health," says WHO epidemiologist Rudi Slooff.

WHO, the World Meteorological Organization, the United Nations, and other bodies are developing several networks of research stations worldwide, in accordance with provisions in the 1992 climate treaty, to monitor various aspects of the environment—the atmosphere, the oceans, and terrestrial ecosystems. "We're discussing how to add disease surveillance to these systems," says epidemiologist Andrew Haines of the University College of London Medical School. The bottom line is to be more vigilant about the health threats from global warming, says virologist Robert Shope, director of the Yale Arbovirus Research Unit. "We need to continue monitoring vector populations," he says. "There are things that could happen that we could anticipate."

–Richard Stone