



INCREASED FLOODING AND CLIMATE CHANGE: CONSEQUENCES FOR HUMAN HEALTH

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Fall 1998

Evidence linking increasingly severe weather, specifically the greater risk of flooding from increases in heavy rainfall events, to the atmospheric build up of greenhouse gases and global warming was presented by some of the country's foremost academics and meteorologists at a congressional briefing on June 3, 1998.

The increased frequency and severity of flooding events, both

in the US and worldwide, believed to be linked to global warming, brings with it an enhanced risk of catastrophic and epidemic disease according to water experts at Harvard School of Public Health and Florida State University. The panel explained that one of the greatest dangers arising from global climate change may be the potential for flooding events to overwhelm human infrastructure resulting in

contamination of the water supply and thereby endangering human health. The panelists concluded that we are experiencing and will continue to experience global warming and a consequent rise in rainfall. What remains to be seen, according to the meteorologists, is whether a new wave of water-borne disease will result, and whether policy makers will have the foresight to anticipate the threat to human infrastructure and human health.

The June 1998 briefing, *Increased Flooding Events and Climate Change: Consequences for Human Health*, was sponsored by the Environmental and Energy Study Institute, The Harvard Medical School's Center for Health and the Global Environment, and the National Institute of Environmental Health Sciences. Dr. Timothy Ford, associate at the Center and director of the water and health program at the Harvard School of Public Health, began the session by pointing out that climbing temperatures are producing increasingly severe weather worldwide. This has resulted most directly and obviously in more and worse floods. Compounding this trend, land use by humans in many cases has altered flood plains or other-

wise has made floods worse than they might naturally be, Dr. Ford said.

Apart from the loss of individual life and property, extreme flooding events bring with them the threat of epidemic disease. Floods can prompt outbreaks in any number of ways. They can

break down sewers and overwhelm treatment facilities, causing the direct contamination of drinking water with disease-laden wastes. In farm areas, drowned and rotting animals can host and then transmit pathogens. As another example, inundated chemical storage facilities can release

Expert Panel

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toxins. In addition, “flooding creates a vast habitat for many of the vectors of disease,” Dr. Ford offered in summation.

To press that point, Dr. Ford noted that during the past spring major floods occurred in South America, Asia, and East Africa. A raft of diseases — all water-related — soon sprang up: cholera, malaria, dengue hemorrhagic fever, conjunctivitis, and a host of other undiagnosed infectious disease. While

the United States has suffered some of its worst flooding in this decade alone, by and large it has avoided subsequent disease outbreaks. But the United States would be shortsighted to continue to rely on such luck. The 1993 outbreak of *chryptosporidium* in Milwaukee that left 400,000 people ill and 70 dead may not appear such an anomaly years from now, according to Dr. Ford.

RAINFALL IS INCREASING

Increasing outbreaks of water-related diseases are the result of a more vigorous hydrologic cycle, or more simply, more moisture in the air due to evaporation of surface heat from global warming. And Dr. Kevin Trenberth, head of the climate analysis section of the National Center for Atmospheric Research in Boulder, Colorado, explained that global warming causes the earth to “sweat,” which adds moisture to the air. That moisture, now available in the atmosphere, fuels weather systems and invigorates storms. At the crux of the matter is the basic principle that warmer air holds more moisture than colder air. With a warming Earth, more moisture will be held above the Earth and periodically dropped onto it.

Explaining the global climate change scenario, Dr. Trenberth noted “there are some certainties.” First, Earth is indeed warmer. Temperatures have increased by about 1 degree Fahrenheit (F) in the last 100 years, and recent years are the warmest in the last 600 years. 1997 was the warmest year on record, 1995 was the second warmest, and the last 10 years has been the warmest decade on record. As further evidence that warming has “really taken off” in the last decade, Dr. Trenberth noted that this past February was 2.9 degrees F higher than normal, “an exceptional number.” The greatest warming occurs in the northernmost parts, he noted, adding that glaciers are melting nearly everywhere and sea level has risen some 6 inches.

Second, greenhouse gases are increasing due to human activity, especially the burning of fossil fuels. Atmospheric carbon dioxide (CO₂) has grown some 30 percent in the last 200 years, a fact and rate that appears attributable only to the Industrial Revo-

lution, Dr. Trenberth said. This figure is borne out by studies conducted on Hawaii’s Mauna Loa since 1958, he added. In addition to CO₂, other greenhouse gases increased by human activity include methane, nitrous oxide (N₂O), and chloroflourocarbons (CFCs). Broken down, CO₂ is believed responsible for 26 percent of the current greenhouse effect — or the current warming, and the other gases for 14 percent. Moreover, these gases have long lifetimes — CO₂ lasts 100 to 200 years — and even keeping emissions constant would still cause an increase in atmospheric concentrations and therefore, more warming, Dr. Trenberth noted. He cautioned that “we need to pay more attention...” as action now can limit the future rate of climate change and damage.

But the main factor in global warming is water vapor, which accounts for 60 percent of the greenhouse effect, he said. This is because global warming is more than an increase in temperature, Trenberth said. In fact, most of the surface heating goes into evaporating moisture, which goes into the atmosphere where it is available to fuel weather systems. More moisture in the atmosphere means more precipitation, and more extreme storms, fueling thunderstorms, rain, or snow storms for example. Total rainfall may not necessarily be greater, but storms will be more vigorous.

According to Trenberth, moisture in North America’s lower atmosphere has increased 10 percent in the last 20 years and precipitation in the United States since the early 1900s has increased about 8 percent. Similar research in China shows much the same trends and other studies have literally counted more individual clouds, thunderstorms, weather fronts, cyclones, snowstorms, and other factors attributable to wetter air, he added.

ROLE OF EXTREME WEATHER EVENTS

Dr. Trenberth offered as an apt analogy the 1997 Red River floods, where dikes historically have held back high water but could not quite handle the extra that came that year. “These extremes are difficult for societies and human infrastructure to deal with and are much more worth paying attention to than simply changes in average temperatures,” he said.

Dr. David Easterling, a research meteorologist at the National Oceanic and Atmospheric Administration’s National Climatic Data Center in Asheville, N.C., noted that precipitation has increased globally, most notably in the higher latitudes of Siberia, Northern Europe, and Canada. That increase has reached the United States, where the last five

years has seen major flooding events.

“Precipitation in the world and in the US has increased over the 20th century by as much as 5, 10, or even 20 percent as you get into higher latitudes, said NOAA meteorologist David Easterling. Easterling cited evidence that the globe will experience a warming between 1 and 4 degrees Celsius. Much of this change will become evident in the frequency of extreme events. Easterling presented evidence from a single and multi-day precipitation events in the US. The warming is most evident in the decline in the number of days when the temperature dips below freezing, especially in the spring. In addition, nighttime temperatures do not dip as low.

Heavy precipitation, as opposed to light rainfalls, are the types of meteorological events that raise concern about potential flooding. He noted that Canada has seen a big increase in such “heavy events.” Since 1910, all areas of the United States have seen more “extreme, one-day events,” with the Northeast and Southern Plains showing as much as a 12 percent increase. The number of days with precipitation over 2 inches has grown throughout the country, except for some areas of the West. The nation as a whole has seen a “distinct” upward trend in “heavy, multi-day events” since 1930. Interestingly, in some cases the increases have been at the expense of moderate events, Easterling noted.

TRICKLE-DOWN EFFECT ON HUMAN HEALTH

Higher rainfall will trickle down to affect humans and the things they build. As alluded to by Dr. Ford, this is most commonly thought of as washed out bridges and broken levees. But for human health, the most crucial question may be whether water treatment facilities can properly handle more of what they treat, said Dr. Joan Rose, professor of water pollution microbiology in marine sciences at the University of South Florida. Such infrastructure will be taxed even by precipitation that falls short of causing floods, she noted.

Compounding the matter of greater rainfall is the fact that many of the world’s cities are already grappling with matters

daunting in their own right, Dr. Rose said. Most of the world’s population — nearly all its “megacities” and most large communities — are on coasts, and more often than not at rivermouths. In short, they are at the world’s most watery places. At the same time, they are dealing with issues of energy efficiency, water management, waste management, and food supply. Population growth makes its own demands on water flows. Dr. Rose offered as an example her home state of Florida, where in the early days water management was handled largely by flood management districts, which by necessity gave way to agricultural irrigation districts, and which in turn gave

way to urban water resource management districts.

For health experts, the global climate change issue is one of precipitation, and, more particularly, one of stormwater management, Dr. Rose said. Stormwater can carry 1,000 times the normal amount of disease-bearing microorganisms; it also carries high levels of metals, pesticides, and other substances depending on where the water is. Since most waterborne diseases stem from organisms in human and animal waste, an especially high premium is placed on the integrity of sewage and wastewater facilities. Taken together, the key for human health is ensuring that stormwater does not “break into” such infrastruc-

ture and does not overtax treatment facilities. Even under non-flood conditions, infrastructure can be damaged and treatment facilities can be pushed well beyond their capacity to adequately treat water, Dr. Rose noted.

The increase in the amount of water coincides with a greater pool of disease that can be water-borne. The recent re-emergence of infectious disease in the world is due largely to newly evolved antibiotic resistance, but also to new,

more-sensitive populations able to host, carry, and transmit it, Dr. Rose said. There are 120 types of viruses that come from fecal matter and can be spread through water. Diarrhea is the most common result, but hepatitis, insulin-dependent diabetes, myocarditis, and meningitis can also occur, she said.

Water-borne disease eruptions are uncommon but not alien to the United States. There are 10 to 20

outbreaks per year in this country that cause 10 to 50 percent of a community to become ill. However, most experts believe only about 10 percent of outbreaks are recorded, Dr. Rose noted. In the best known case, the 1993 Milwaukee incident occurred after treatment facilities failed to “catch” highly resistant oocysts created by the waste-borne *chryptosporidium* protozoan, she said.

RAINFALL-DISEASE CONNECTION

As for direct connections between rainfall and disease outbreaks, a Pennsylvania study found high concentrations of *chryptosporidium* and the related *giardia* in stormwater running into rivers, Dr. Rose said. Communities can be affected by just three to five days’ exposure to such organisms. Moreover, peak concentrations of them coincide with short-term, extreme precipitation events that, not surprisingly, often overwhelm treatment facilities, she noted.

There remains a wealth of questions to be answered and connections to be made regarding

water-borne disease and weather patterns, which health experts are beginning to address using 50 years of government data, Dr. Rose said. So far, researchers have found a seasonality to outbreaks: most occur in spring and summer — typically the times of greatest rainfall — and the least occur in winter. Experts are also beginning to determine how wastes and attendant diseases are transported to treatment facilities. For example, Pennsylvania is a “groundwater state,” and outbreaks with groundwater and wells as their sources are predominant there. Research has also found outbreaks clustering along certain waterways, Dr.

Rose noted. Finally, studies have found a high — 90 percent — correlation between extreme precipitation and disease incidents, and the 1983 El Nino phenomena with its high rainfall coincided with a high number of outbreaks, she said.

In terms of where science needs “to go” to understand current trends and forestall their effects, Dr. Rose suggested that the different risk assessment models now in play need to be tied together to form a cohesive approach. Researchers need to understand the capabilities of climate models, how to predict the geographic changes that might occur, and how to tie that to runoff, and water quality risk assessment models, she said. Interdisciplinary work also is sorely needed. Water quality issues flow through a great number of policy sectors, and since watersheds know no political boundaries, officials from any number of states, counties, and localities will need to become engaged when even one river or other water source is at stake, Dr. Rose said.

For details about the presentation, please call Dr. Eric Chivian, director, or Rita Chang, executive director, at the Harvard Medical School’s Center for Health and the Global Environment at 617-432-0493

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