

## Global Climate Change: Beyond Sunburn

Environmental health professionals and public policymakers are well acquainted with the human health effects of fossil fuel usage, such as respiratory ailments caused by air pollution. However, fossil fuel use may also cause dramatic changes in the global climate, spawning impacts on human health that cannot be readily quantified or prevented.

Some scientists have warned that the atmospheric accumulation of gases stemming primarily from fossil fuel combustion, including carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide, the "greenhouse gases," could increase the global surface temperature by 1.5–4°C. Such warming if it occurs, could produce extreme weather events, including droughts and heat waves. Landscapes may also change, as plant and animal species find climate conditions unsuitable in their native habitats. Global warming may also expand the range and incidence of vector-borne diseases, increase the incidence of seafood poisoning, exacerbate heat-stress related mortality, worsen the effects of air pollution, and undermine food supplies, especially in developing countries. Climate-related effects might also be accompanied by health effects associated with ozone depletion, caused by emissions of chlorofluorocarbon gases. Effects would include increased skin cancers and cataracts, as well as possible impacts on the human immune system that may weaken resistance to some infectious diseases.

These potential health-related effects of global environmental change were the subject of a 1990 report by a World Health Organization task group. Noting the uncertainty surrounding estimates or predictions of global climate change, the WHO task group adopted several assumptions on which its assessment of health effects is based: a 3°C increase in the average global surface temperature; greater warming effects in the high latitudes of the Northern Hemisphere, where temperature increases could average 8–10°C; lesser warming effects in the Southern Hemisphere and in equatorial regions, where temperatures could increase by 3°C or less; and an increase in ultraviolet radiation, especially ultraviolet-B radiation, by up to 20–25% by the year 2050, though increases would vary by latitude.

The task group warned that predictions about health effects "have to remain very general and speculative" because of inadequate data

and noted that the distribution of health effects among the world's population will be determined by age, socioeconomic status, level of hygiene, and, for skin cancer, skin pigmentation. The task group is in the process of revising and expanding the 1990 report and is expected to release an updated version in early 1995.



### Cancers and Cataracts

The potential health effects associated with global climate change may be categorized as direct or indirect. Among the direct effects cited in the WHO report are those associated with ozone depletion and the resulting increases in exposure to ultraviolet radiation.

Sunlight contains ultraviolet-A, ultraviolet-B, and ultraviolet-C radiation, but only UV-A and UV-B reach the earth. UV-B levels are primarily affected by stratospheric ozone, which helps absorb the radiation before it reaches the earth's surface. Stratospheric ozone has declined by as much as 3% over the Northern Hemisphere in the past 20 years, though ozone concentrations vary seasonally. The greatest decreases occur in winter and spring months, according to the WHO report, which noted that insufficient data exist to evaluate stratospheric ozone measurements for the equatorial zone and the Southern Hemisphere.

The incidence of typically nonlethal basal cell and squamous cell skin cancers is directly correlated to the amount of exposure to UV-B radiation, according to Steven Lloyd, a post-doctoral fellow at Johns Hopkins University's Applied Physics Laboratory. Said Lloyd, "If you spend twice as much time outside, you are twice as likely to come down with [non-melanoma] skin cancers." An estimated 1% decrease in stratospheric ozone produces a 2% increase in nonmelanoma skin cancer, he noted. When ozone decreases by more than 5%, skin cancer rates increase exponentially.

However, skin pigmentation helps to determine susceptibility to skin cancer, Lloyd commented, noting that fair-skinned, freckled individuals who burn easily are most at risk. Lloyd also pointed out that skin cancer effects will vary geographically. "Ozone loss is not uniform," he said. "There are bigger losses toward the North and South Poles, and virtually no losses at the equator."



**Margaret L. Kripke**—Ultraviolet radiation can decrease immunity to some bacteria.

U of Texas

Incidence of malignant melanoma is correlated to exposure to sun, but not to total exposure. Instead, one-time exposures that produced severe burning and blistering may be related to the appearance of melanoma many years later, Lloyd said. The melanoma may not appear where the sunburn occurred but may show up in the groin or armpits. "As soon as the melanoma is big enough to detect, it has probably traveled through the lymph glands," said Lloyd, which "is why it shows up in the arms and the groin." At that point, the melanoma may also have spread to internal organs.

Unlike other skin cancers, malignant melanoma is not readily produced in animals exposed to UV-B radiation, raising the question of UV-A's role in melanoma initiation, according to Janice Longstreth, technical group leader of environmental management and planning for Battelle Pacific Northwest Laboratories. Longstreth cited a fish study that suggested that UV-A could be effective in producing melanoma, while other data suggest that UV-A can act as a promoter or co-factor in non-melanoma development.

UV-B also affects the eye. Cataracts, according to the WHO report, are a leading cause of blindness in many parts of the world. Similar to the way exposure to the sun yellows plastic or newspaper, UV-B also "photo-ages" the lens of the eye and blurs vision, Lloyd explained, though the correlation between UV-B and cataracts is not as strong as the connection between UV-B and nonmelanoma skin cancers.



### Immune System Effects

Depletion of the ozone layer may also affect the human immune system, though "what we know about UV radiation and infectious disease comes exclusively from animal models," according to Margaret Kripke, chair of the Department of Immunology at the University of Texas M.D. Anderson Cancer Center. Kripke, with colleague Amminikutty Jeevan, has researched the effects of UV radiation on immune response.

Kripke said exposure to UV-B radiation triggers skin lesions caused by the herpes simplex virus in individuals already infected. "There have been experiments in animal models to try to determine the mechanism of UV-B in triggering skin lesions," she noted. "There is some evidence that it is the immunological effect of ultraviolet light that causes the outbreak of the disease."

Other animal experiments have involved the mycobacteria that cause

tuberculosis and leprosy, Kripke said. "Those studies have indicated that exposure to ultraviolet radiation can decrease immunity to the bacteria and inhibits their clearance from lymphoid organs." Moreover, exposure to UV-B before infection by the mycobacteria can accelerate the course of the infection.

Whether UV-B radiation would suppress immune responses to all infectious diseases is unclear. "My guess is that there will be certain infectious diseases that are more likely affected," Kripke said. "Ultraviolet radiation interferes mainly with immune system responses that are mediated by T-lymphocytes. It has much less effect on the antibody responses," she commented.



### Respiratory Effects

The effects of ultraviolet radiation are not the only direct impacts that may be associated with global environmental change. The WHO task group cited two other direct health effects: the impact of climate on air pollution, and the impact of rising temperatures on heat stress mortality.

Concerning air pollution, the task group noted the importance of wind speed, temperature, wind direction, and precipitation in determining concentrations of air pollutants, but also acknowledged the difficulty of predicting accurately how warming might affect those climate-related factors. Some regions may experience more frequent and prolonged periods of atmospheric stagnation caused by low wind speeds and thermal inversions, while other regions may experience fewer such periods. Changing climate conditions may require revisions in air pollution control programs, the report said.

Climate change will probably not, by itself, produce a net increase or decrease in fossil fuel consumption, the task force said. But climate change, coupled with depletion of stratospheric ozone, will increase ozone pollution at ground level, which can irritate and inflame the respiratory tract. Ozone may have greater impacts when combined with other pollutants, such as acids, pesticides, chlorofluorocarbons, and metal aerosols, the task force suggested.

That contention is partially supported by research conducted by Jerold A. Last, of the Department of Internal Medicine, Pulmonary Division, at the University of California School of Medicine in Davis. Last has exposed animals to high concentrations of acid aerosols and ozone. "The exposure of rats to oxidants in the presence of acid aerosols increased the effects of oxidants, which directly damage the lung," he

said. More research is needed to determine the effects of chronic exposures, Last noted.

Although much remains to be learned about the impact of climate change on air pollution, the WHO task group observed that "the potential exists for major changes in the concentrations, duration and types of pollution," which may have significant effects on air pollution morbidity and mortality worldwide.



### Heat Stress

Heat stress, another potential direct health effect, is a relatively minor threat to human health overall but is an important factor for "high-risk groups," the task group said. Healthy individuals will typically be able to adjust to warmer temperatures and avoid heat stress ailments, ranging from mild, reversible cardiovascular effects to severe tissue damage and death, the report said. But for less healthy individuals, even mild heat stress can produce heat-related ailments. Health risks from heat stress are greater in areas where cooling systems are inadequate or water supplies are limited. As the task group noted, "under heat wave conditions, the availability of water will become extremely critical for human survival."

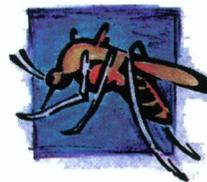
The impact of heat on mortality may also extend beyond direct effects like heat exhaustion and would especially affect regions that are not accustomed to consistently hot weather, according to Laurence S. Kalkstein of the Center for Climatic Research in the University of Delaware's Department of Geography. For example, the mid-Atlantic or midwestern regions of the United States would experience greater heat stress-related mortality than would places that are consistently hot, an outcome he attributes to acclimatization.

Kalkstein defines heat stress broadly, to include "the whole range of things we could die from," including heart conditions and respiratory ailments. Although such ailments are not usually classified as heat stress-related mortality, Kalkstein believes increased mortality from these illnesses are often attributable to heat. In a chapter he authored for an EPA report on climate change issued in 1989, Kalkstein said mortality in New York City during a July 1980 heat wave increased by more than 50% above normal on the hottest day of the heat wave. In that report, Kalkstein

estimated 320 heat-related, summertime deaths from all causes.

By applying climate scenarios to his mortality models, Kalkstein can estimate heat-related mortality in a warmer environment. If levels of a chief greenhouse gas, carbon dioxide, are double in 2060 the levels that prevailed 100 years earlier, the United States would experience a 7-fold increase in heat-related mortality, assuming that people fail to adjust to the heat. If acclimatization occurs, a 4-fold increase would be expected, he said. For New York City, a 4-fold increase in mortality would produce 880 summertime deaths attributable to heat.

Kalkstein noted that disagreement exists about whether warming would produce offsetting effects by lowering winter mortality rates. "I dispute that," he said, because "we don't have much of a winter impact to begin with." Cold weather-related mortality stems primarily from indoor exposure to infectious diseases, he commented. A small increase in temperature will not drastically alter people's willingness to go outdoors or remain inside, he said.



### Vectorborne Diseases

Venturing out of doors may be a somewhat less pleasant activity in the potentially warmer, more volatile climate of the future. In addition to coping with heat stress, ultraviolet radiation, and air pollution, residents of developed countries in temperate climates may be faced with new threats from infectious diseases, many of which are spread by vectors that may be more numerous and difficult to control.

As with the other climate-related health impacts, assessments of the impact of climate on vectorborne diseases are uncertain. "Even the experts don't all agree as to whether certain areas will warm or not, whether they will receive more or less rain," observed Robert Shope, professor of epidemiology at the Yale University School of Medicine.

Yale School of Med.

"Some vectors have very stringent requirements for their ecosystems. Some can't survive if the temperature gets too high or too low or if the rainfall is too high or low," he said. Vectors relying on a particular habitat, such as forests, will disappear if their habitat is eliminated, Shope noted.

A 3°C warming in the United States could increase



**Robert E. Shope**—Disease vectors may be increased or decreased by climate change.

the range of *Aedes aegypti*, a mosquito species that can carry the viruses dengue and yellow fever. *Aedes aegypti* is killed by freezing temperatures. At latitudes farther north than Memphis Tennessee, for example, this mosquito is present only during the summer. A 3° warming could increase the areas in which *Aedes aegypti* would be present during more of the year, Shope said. Moreover, in places where the mosquito is present year-around, the mosquito may become more active.

Warming will also affect the agents carried by the vectors, Shope said. "A virus like dengue requires a warm temperature in order to multiply within the mosquito," he said. Up to a certain point, higher temperatures will shorten the period in which a mosquito, after consuming an infected blood meal, can transmit the virus.

Forms of dengue vary in severity, to which one can be exposed in sequence. One form, "classic dengue," is not fatal, but causes a fever, body aches, and severe headaches. If infected again, an individual runs the risk of developing a second form of dengue that produces hemorrhagic fever, which is fatal in about 5% of cases, though mortality may be lower in areas where physicians know how to treat the disease.

Cuba experienced deadly outbreaks of dengue in 1981, after a previous outbreak in 1977-78. Costa Rica experienced 5000 cases of dengue fever in 1993 and could experience an outbreak of the more severe form if "another serotype is introduced and they don't control mosquitoes," said Shope.

The United States, fortunately, lacks cases of dengue, though it's possible it could be introduced into a U.S. city. While warming might increase mosquito populations and improve conditions for disease transmission, those conditions alone would not ensure an outbreak in the United States, Shope explained, noting that infected individuals would have to enter cities where the vectors, *Aedes aegypti* and *Aedes albopictus*, are also present. However, if a dengue outbreak began "it would not have to amplify a lot for large numbers of cases to occur," he noted.

The United States must also pay attention to the potential for yellow fever cases, Shope advised. Yellow fever, which produces vomiting, a high fever, and may cause jaundice and hemorrhaging, is fatal in 10-50% of the cases. The disease is present in jungles, but could be brought into nonjungle areas by travelers. Shope noted that American travelers are advised to be

vaccinated before visiting countries where yellow fever is present. Still, it is possible for infected individuals to return to the United States and transmit yellow fever to the mosquito vectors.

"The chances of that happening are not very great," Shope said. "But if it did happen, I doubt it would be recognized right away. Very few cases have been seen [in the United States], and physicians may mistake yellow fever for cases of infectious hepatitis-B. It could take many cases before public health officials would recognize a yellow fever outbreak, Shope commented, and ample supplies of vaccine may not be readily available.



Harvard Med. School

**Paul Epstein**—Algae may be early indicators of climate change.

The incidence and location of malaria outbreaks is also expected to be affected by climate change, according to the WHO task group. Of 11 kinds of vectorborne diseases assessed by the task group, malaria is the most prevalent, producing an estimated 270 million cases a year worldwide, primarily in tropical and subtropical areas.

Increased temperatures and rainfall may improve conditions for the *Anopheles* mosquito, which carries malaria.

Malaria may reappear in areas where it was once prevalent, before vector-control efforts, although the disease is not expected to be as prevalent as before. Areas where malaria is currently prevalent may experience more significant effects, the report said.

Robin Carper, co-author with Andrew Carper of Princeton University of an article on climate change and vectorborne diseases in the 30 October 1993 issue of *The Lancet*, noted that the United States already possesses the appropriate climatic conditions for vectorborne diseases, especially malaria. "We should have the disease here, and would if it weren't for the vast mosquito control efforts," said Carper. Though climate change may improve conditions for mosquito populations, malaria is not likely to become a public health problem in the United States because the *Anopheles* mosquitos that transmit the disease are losing habitat, she said.

But Carper said viruses that cause various types of encephalitis are of concern because they are carried by *Aedes aegypti* and by *Aedes albopictus*, or Asian tiger mosquitos, which were introduced in the United States in the late 1980s. *Aedes aegypti* "tend to breed in just about anything: bottle caps, plastic wrappers, tire dumps," she said. "The habitats we do create are just perfect for them, and are hard to get to" for control efforts.

The types of encephalitis vary in severity, according to the 1989 EPA health effects report. In a section authored by Janice Longstreth, the EPA report said encephalitis viruses can range in severity from mild, flulike symptoms to fatal cases of central nervous system disease. Encephalitis is characterized by fever and inflammation of the brain, which may be reflected in decreased levels of consciousness and neurological problems.

The potential impacts of climate on vectors underscores the need for continued efforts in vector control, according to Shope. Currently, Shope said, the United States is lagging in developing new pesticides and vectors are growing more resistant to pesticides in use.

Similar concerns are expressed by Dov Borovsky, professor of insect biochemistry at the University of Florida, where work is underway at the university's Medical Entomology Laboratory to develop insecticides isolated from the insects themselves. "Insects are getting quickly resistant to most pesticides," Borovsky noted. Moreover, "insects are resourceful. The more pressure you put on them, the 10 percent that are left are more resistant than the 90 percent you've killed. And they [survivors] reproduce," he commented.

Infectious disease control is also hampered by growing resistance of agents to drugs that are typically used for treatments, according to John LaMontagne, director of the Division of Microbiology and Infectious Diseases, at the National Institute of Allergy and Infectious Diseases. Malaria, for example, has become increasingly resistant to the drug that has long been used for treatment. A newer, more expensive drug is also available for treatment, but "there's no assurance that the malaria parasites will stay sensitive" to the newer drug, LaMontagne said.

A vaccine is being explored that could inhibit transmission of malaria from humans to mosquitos. And according to LaMontagne, "There have also been attempts to genetically engineer mosquitos that are resistant to malaria because they can't sustain replication of malaria in the salivary gland."



**Food Supply**

New or increased threats from vectorborne diseases may be accompanied by dwindling food supplies, especially in developing countries. Developing countries may have to contend with food shortages caused by increases in adverse weather events such as heat waves, droughts, and monsoons.

The WHO task group noted that glob-

al environmental change can have multiple effects on agricultural production, including changes in the types of crops cultivated, changes in crop yields and livestock production, and loss of land for cultivation due to increases in the sea level.

Temperate areas or areas with colder climates would tend to enjoy higher yields and an extension of arable lands northward, the positive effects of higher temperatures, increased solar radiation, and rainfall, the task group said, though whether climate change will produce such effects is unclear. Semi-arid regions, which have already suffered declining agricultural productivity and food shortages because of droughts in the 1980s, are expected to be negatively affected by climate-related disruptions. But whether negative effects occur depends on whether alternative food sources, such as imports from countries enjoying higher yields, can offset the yield declines. Most at risk from any climate changes are those regions suffering from overpopulation and a marginal agricultural capability, the task group noted.

Even if climate change does not negatively impact agricultural output, climate change will likely reduce the variety of crops being cultivated, the WHO report said. Infants, children, and pregnant women will especially be at risk for nutritional deficiencies as the variety of crops declines. Indeed, the number of malnourished people worldwide is already expected to increase during the next two decades, without the impacts of climate change, according to the task group.

### Early Indicators of Climate Change

Global environmental impacts would not be confined to terrestrial organisms. Marine ecosystems are already

showing signs of climate and environment-related stress that is undermining marine life and potentially threatens humans who consume seafood, according to Paul R. Epstein, a faculty member of the Harvard Medical School and a member of the WHO panel that will be updating the organization's global change health effects report.

For example, marine ecosystems are being threatened by an overgrowth of algae blooms, to which toxic organisms may attach themselves and thereby contaminate fish and other seafood. Some algae blooms, such as red tides, are themselves toxic and also cause shellfish poisoning. Algae blooms are also a reservoir and an amplifier for cholera, which can pose a serious health threat for developing countries with poor water and sanitation. If treated quickly,

cholera can result in a 1% mortality rate, but mortality can be much higher where water, sanitation, and health facilities are inadequate, Epstein said.

Increased use of nitrates and phosphates, coupled with the loss of wetlands that filter out pollutants, are enhancing algae growth, as is the overharvesting of fish and shellfish, Epstein said. Against this backdrop, climate change appears to exacerbate algae growth. "It seems to play a role in warming systems that are already rich and ready to go," Epstein commented, noting that warmer conditions also seem to be favorable to more toxic species.

In 1987, several unusual events occurred along the North American east coast that illustrate the vulnerabilities of marine ecosystems. That year, the coast was affected by the Gulf Stream, a strong ocean current, and by a naturally occurring climate phenomenon known as El Niño, which warmed ocean temperatures. A die-off of eel grass, a type of vegetation which grows on the ocean floor, occurred, and an organism that previously had been found only in the Gulf of Mexico and apparently had been transported by the Gulf Stream caused neurotoxic shellfish poisoning off Cape Hatteras in North Carolina.

In New England, deaths of numerous dolphins and humpback whales were attributed to algae blooms, viruses, and exposure to polychlorinated biphenyls, which decreased the immunity of the animals, Epstein said. At Canada's Prince Edward Island, consumers of shellfish that was poisoned by an algae diatom developed gastroenteritis as well as temporary and sometimes permanent amnesia.

Epstein believes algae may serve as early indicators of climate change. At present, the evidence seems to suggest that warming effects are underway. For example, reports of contaminated seafood are growing, Epstein said, as is the appearance of red tides at higher latitudes and in locales where they have never before appeared, including New Zealand and the southern tip of South America, where in 1991 shellfish poisoning occurred in the Straits of Magellan.

The importance of ecosystem vulnerability has not gone unnoticed by the WHO panel examining the health effects question. Said Epstein, "We're trying to understand the interaction between ecosystem vulnerability and climate change and how that's going to affect some biological indicators."

### Biodiversity and the Search for New Drugs

While biodiversity is obviously an important factor in the health of ecosystems, preserving plant and animal species is also

directly important to human health because, as the WHO task group observed, "many animal and plant species have provided mankind with food, drugs and other useful products."

The potentially sweeping human health impacts which may be fostered by global change will heighten the importance of developing new drugs, but global change is also threatening a natural source of new drug discoveries. The as yet unknown benefits of many plants "can be regarded as a large untapped resource that could be developed by future generations," the WHO report said. Efforts to identify medicinally useful plants are underway at the National Cancer Institute, which is collecting plants in over 25 countries, primarily in tropical regions, according to Gordon Cragg, chief of NCI's Natural Products Branch.

Future efforts to develop drugs from plant species will continue to be hampered by development and destruction of rainforests which will result in extinction of many plant and animal species and the permanent loss of their existing and potential benefits. The destruction of the rainforest illustrates how a single human activity can impose multiple strains on the environment: by contributing to greenhouse emissions when forests are burned down, by reducing a natural "sink" for greenhouse gases, and by eliminating plant species which may contain treatments for climate change-related illness.

"For both the ecosystem and climate system changes, the driving forces are both development related," observed Epstein. The economic and political policies driving that development "are ultimately what's making the ecosystem vulnerable," and increasing the rate of climate change.

As the WHO task group observed, humans "have influenced the environment since the first settlements were built and the land cultivated." Those impacts, however, were easily "absorbed by the resiliency of the environment." But growth in human populations and technological advances have profoundly impacted the environment, and "may well exceed its capacity to absorb them."

**Karen Breslin**

Karen Breslin is a freelance science writer in Lakewood, Colorado.