CLIMATE CHANGE

No Way to Cool the Ultimate Greenhouse

When the Clinton Administration announced its Climate Change Action Plan last week, some press accounts called it an effort to halt greenhouse warming. To greenhouse experts, however, cutting emissions of greenhouse gases to 1990 levels by the end of the decade—the goal of the plan—will only delay the inevitable. "It's a good first step," says Jerry D. Mahlman, director of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, "but it is important to remember that stabilizing emissions has nothing to do with stabilizing greenhouse gas concentrations" and thus stabilizing climate. Such modest conservation measures, as a recent study shows, will buy humanity valuable time to adapt to the greenhouse world, but they will have little effect on how warm the global climate ultimately becomes.

"Ultimately," to these researchers, means something well beyond the decade-long horizons of politicians or the century-long time scale of most scientific discussions of greenhouse warming. To really size up what the world is facing, they say, you have to look hundreds of years down the road. That's what James Kasting of Pennsylvania State University and James Walker of the University of Michigan did in their study, which appeared in the journal *Palaeogeography, Palaeoclimatology, Paleaoecology*. They found that nothing but the most draconian controls can prevent carbon dioxide from building up to four or more times its preindustrial level, causing perhaps 10°C of warming.

In tracing the rise of carbon dioxide into the far distant future, Kasting and Walker took into account the rate at which the ocean and vegetation remove the gas from the atmosphere. They also assumed that conservation may slow the depletion of fossil fuels but won't stop them from being exhausted in the end. They then ran their model several times for different conservation scenarios.

If the rates of fossil-fuel and forest burning continue to increase as they have in the past few decades, Kasting and Walker found, carbon dioxide will pile up in the atmosphere until in the early 23rd century it reaches 7.6 times pre-industrial levels. If fossil-fuel burning is held to today's level, the peak moves back to the year 2700, but it stays nearly as high: 7 instead of 7.6 times the pre-industrial value. Ending the destruction of forests would only lower the peak to a quadrupling of carbon dioxide. These conservation measures have little effect on the ultimate greenhouse because oceans and plants take up carbon dioxide so much more slowly than human beings release it. A modest slowing of emissions simply doesn't give these natural sinks enough time to catch up.

Under scenarios like Kasting and Walker's, says Mahlman, "it's hard not to expect substantial change." Along with dramatic warming, it might include tens of meters of sea level rise and a stagnation of the deep sea (*Science*, 30 July, p. 553). According to the model, the only way to limit the rise in carbon dioxide to a doubling of pre-industrial levels, expected to cause 3° to 5° of warming, would be to cut the present emission rate by a factor of 25—something neither the developing nations nor the industrialized ones are likely to contemplate.

Not that Kasting and Mahlman doubt the value of delaying the carbon dioxide peak, the one thing conservation measures such as the Climate Change Action Plan can do. After all, humanity will have to do quite a bit of adapting to the ultimate greenhouse, and the more time it has, the better. Says Mahlman, "The amount of adaptation [to global warming] is large. Fortunately, it takes a long time to get there."

–Richard A. Kerr

EPIDEMIOLOGY

New Sellafield Study Poses a Puzzle

LONDON—Three years ago, an epidemiological study rocked the nuclear industry by suggesting a link between exposure to radiation among men and leukemia in their children. The study, by the late British epidemiologist Martin Gardner, focused on workers at the Sellafield nuclear reprocessing plant in northwest England and had profound implications for the nuclear industry: If a causal link between exposure and cancer could be proven, occupational exposure limits to radiation would have to be tightened and British Nuclear Fuels, the operator of Sellafield, might be open to litigation from the affected children and their relatives.

Center of controversy. The Sellafield reprocessing plant in northwestern England, a focus of cancer epidemiology.

The study was widely regarded as statistically sound and extremely well conducted, but scientists found its conclusions hard to swallow (*Science*, 6 April 1990, p. 24). And follow-up studies in several countries added to the skepticism when they all failed to provide a shred of evidence to support Gardner's conclusions (*Science*, 2 October 1992, p. 31). But now comes a report* from Britain's Health and Safety Executive (HSE), the government body that monitors health and safety in industry, that both supports and refutes Gardner's findings.

Researchers sought out all children from West Cumbria (the area where Sellafield is based) who had been diagnosed with cancer before the age of 25 and whose fathers had worked at the plant before the diagnosis. As a control, they found Sellafield workers' children who had not developed cancer by the age of 25. The researchers then compared the occupational histories of the two groups of fathers: Their exposure to internal and external radiation, exposure to chemicals and involvement in radiological or other incidents at the plant.

This comparison turned up only "fragile evidence," the HSE says, that long-term cumulative exposure to radiation by fathers before the conception of their children was linked to an increased risk of the child developing leukemia and non-Hodgkin's lymphoma. In particular, there was no association between external radiation dose in the 12 weeks before conception (the period during which the impregnating sperm would have formed) and the risk of cancer in the children.

But the HSE found a very different story in the village of Seascale, 3 kilometers south of Sellafield. The rate of leukemia and non-Hodgkin's lymphoma among children whose fathers worked in Sellafield and lived in Seascale when they were born was about 14 times the national average. The HSE's report says that it found a "strong association" with the cumulative dose of radiation that the fathers had received before conceiving the children who later developed cancer. In addition, these fathers had received "strikingly higher" radiation doses than other Sellafield workers who lived in Seascale.

According to the HSE report, the odds

*"*HSE Investigation of Leukemia and Other Cancers in the Children of Male Workers at Sellafield."* Health and Safety Executive.

against such a cluster of affected children occurring in Seascale by chance are 4000 to 1. The problem is, no one has a clue what could have caused the cancers only in Seascale. An HSE official says: "We don't feel we are in a position to make any causal explanations on the basis of what we have found."

Whether the Seascale findings prove or disprove Gardner's hypothesis that radiation causes mutations in sperm is still very much in contention. "The cause must be some factor that is associated with radiation that applies particularly to the Seascale fathers," says Hazel Inskip, an epidemiologist and statistician who went to work with Gardner at the Medical Research Council's Environmental Epidemiology Unit in Southampton shortly before he died and has taken over his work. "It may be some associated exposure that we may not ever identify. There is some evidence from animal experiments that chemical exposures can cause tumors in later generations."

But the skeptics are also using the anomaly to support their case. The HSE discounts Gardner's explanation, the official says, and instead points to a theory advanced by Leo Kinlen of Oxford University known as "population mixing." Kinlen recently published a study that found some of the excess cases of leukemia and non-Hodgkin's lymphoma in Seascale occurred in children who were not born there and whose fathers were not linked with the nuclear industry. He suggests that the cause may be some infective agent, and that the risk of childhood leukemia may be enhanced when there is an influx of people who come to live and work in a geographically isolated area, bringing the agent with them. This theory has one big drawback however: No one has so far been able to identify an infective cause for childhood leukemia.

James Neel, professor of human genetics at the University of Michigan, who has studied the Hiroshima and Nagasaki atomic bomb survivors and found no increase in leukemia among their children, says the Seascale finding "is either a statistical aberration or else factors which have not been identified are at work—but not radiation."

How this plays out could have important legal implications. An English court has already ruled, in a landmark case last month, that radiation was not to blame for the cancer that developed in the children of two men who had worked at Sellafield.

Gerald Draper, director of the Childhood Cancer Research Group at the University of Oxford, believes he will be able to resolve the confusion by attacking the problem from a different direction. Using a blanket approach, he has identified 30,000 children throughout Britain with leukemias and other cancers and is identifying their parents from birth records. He is then checking whether the parents appear in the National Registry of Radiation Exposure; if they do, records of their radiation doses can be obtained.

The results of his study are not due for another 15 months. Asked whether it will settle once and for all the question of whether parental radiation exposure is linked to childhood cancer, Draper says: "I devoutly hope so."

–Sharon Kingman

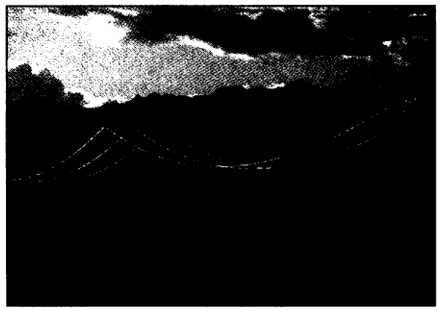
Sharon Kingman is a science writer based in London.

EPIDEMIOLOGY

EMF-Cancer Links: Yes, No, and Maybe

The controversy over whether or not low-level electromagnetic fields (EMF) can cause cancer has been smoldering for 15 years. This month it got a little hotter—but there's still more smoke than fire. At the beginning of October, writer and EMF gadfly Paul Brodeur brought out his latest book exposing a purported EMF-cancer connection, entitled *The Great Power-line Cover-up*. Right on his heels, however, on 9 October, the *British Medical Journal* weighed in with two serious scientific assessments of the cancer risk. Unfortunately for those who long for a conclusive answer, one study found only a slight positive association between EMF and cancer, and the other found no link at all. Together the studies "artfully provide middle-of-the-road type of evidence," says Dimitrios Trichopoulos, chairman of the epidemiology department at the Harvard School of Public Health.

Even the positive study wasn't very positive. It was led by epidemiologist Jorgen Olsen of the National Cancer Registry of Denmark, and his team looked at all Danish children diagnosed over the past two decades with either leukemia, brain tumors, or malignant lymphomas, the three most common childhood cancers. After choosing controls from the general population, the researchers then established how close the cases and the controls lived to power lines and for how long a period of time. The Danes reported that the highest exposure level—children living within 25 to 50 meters of the most powerful transmitting stations—carried a slightly increased risk for all cancers. That conclusion is, however, based on "very small numbers," Olsen says: six cancer cases out of approximately 600 children who fit these criteria. The researchers also found an increased risk for lymphomas in this high-exposure category, although again adding a caveat that it was based only on three cases. But they found no elevated risk at all for brain tumors or leukemia.



PETER HENDRIEL/THE IMAGE BANK

Lines of debate. Positive and negative study results obscure any connection between cancer and power lines.

In an accompanying editorial, Gerald Draper, director of the Childhood Cancer Research Group of the University of Oxford, pointed out that even the lymphoma effect was found only "in relation to a grouping of exposure categories chosen after examination of the data." Epidemiologists are traditionally suspicious of this kind of after-the-fact data manipulation; Patricia Buffler, dean of the school of public health at the University of California, Berkeley, says that changing the exposure categories after gathering all the data is "just not the scientific method."

The second study was by Finnish researchers, led by Pia Verkesalo of the University of Helsinki and Markku Koskenvuo of the University of Turku, and no caveats were required. It was simply negative. The investigators located 135,000 children living within 500 meters of overhead powerlines in Finland. That group, the Finns reported, had only 140 cases of cancer versus an expected 145 cases in such a population, and "no statistically significant increases were observed in leukemia, lymphoma, and overall cancer in children at any exposure level."

So what is one to make of all this? Not much, according to Draper, who still agrees with the conclusions of major reviews of EMF published last year by the Oak Ridge Associated Universities and by Britain's National Radiological Protection Board (*Science*, 11 December 1992, p. 1724). Both panels concluded that no convincing evidence of an EMF-cancer link had yet been found. Yet Draper's editorial also noted that, because of studies such as the Danish investigation, the possibility that EMF may cause some cases of childhood cancer "cannot be dismissed." Of course, as Trichopoulos, one of the authors of the Oak Ridge review, observes, the inability to rule the connection out may be because "nobody can prove" the nonexistence of a phenomenon.

–Gary Taubes