Environmental Strategies with Uncertain Science

S. Fred Singer

Dealing with science—and scientists—presents a major frustration for those who design or administer environmental policies. Contrary to popular perceptions, science is seldom neat, clear, and unequivocal. There are usually many scientific voices, and they often carry conflicting messages. This causes problems for politicians, lawyers, and administrators, who come to these issues from a different culture and find it difficult to cope with scientific uncertainty. It is to them that this essay is directed.

Why Use Science at All?

A politician or administrator may be tempted to deemphasize science, or to ignore it altogether, when making environmental policy decisions. This is especially the case when there is real controversy about the scientific facts or predictions. One is sometimes faced with the argument that since we know *how* to control the polluting emissions, we should go ahead, apply the technology, and avoid all the arcane scientific controversy that may not get settled soon, if ever.

But it is potentially dangerous—and quite costly—to ignore science, even when it is uncertain. Let me count the ways:

- An understanding of the *natural* trends and variability of environmental conditions is necessary to identify the additional effects of human activities. There are often natural sources of the same or similar pollutants from human activities such as the volcanic emissions of sulfur and chlorine compounds, hydrocarbons from trees, smoke from forest fires, and a variety of esoteric substances from oceanic life forms. A failure to understand or acknowledge the natural sources of these pollutants may lead to an expensive pollution-control program that has little effect on the ambient pollution level.
- Technology and a scientific understanding are necessary to monitor the state of the environment and to interpret the data properly. For example, global temperature data are affected by increasing urbanization, which creates "heat islands" that misleadingly simulate a global temperature increase.
- Research and development are important to lower the cost of pollution control by developing less polluting industrial processes, agricultural practices, and better pollution-control techniques.
- Finally, a scientific understanding of the effects of policy change is necessary to estimate the *benefits* of environmental policies. In the absence of even crude estimates of the benefits of environmental policies, it is not possible to conduct any rational analysis of the desired degree of pollution control. The danger in relying solely on technology-based approaches is exemplified by the frequently ex-

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pressed attitude, "We are not sure of the benefits, but we've got this great new control technology. . . ." Scientific inputs are especially crucial for refined estimates of the *marginal* benefits of tightening control measures. For example, to evaluate the proposed acid rain legislation, we need an estimate of the incremental benefits from reducing sulfur dioxide emissions by another 10 million tons per year (on top of the 8 million achieved by current controls). And what is the rationale for the 10 million ton reduction as against 2 million or 5 million, or against removing all 20 million tons of sulfur?

For those who are allergic to benefit-cost analysis altogether and eschew, for example, expressing "expected lives saved" in dollar terms, we can reword the issue as follows: given a finite, and usually quite limited, amount of resources (best measured in dollars), how do we save the largest number of lives? This question, of course, leads us quite directly into comparative risk analysis. For example, can we save more lives and prevent more illness or injury by further limiting automobile emissions of nitrogen oxides, by installing more air bags, or by spending the funds on increased highway safety? I do not know any way of dealing with such issues except by applying lots of science, usually quite multidisciplinary, coupled with appropriate economic analysis. This rational approach contrasts sharply with strategies that demand the use of "best available technology—cost be damned" or with the even more irrational approach that sets standards requiring technology that is not yet available or even attainable.

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Why Is Science Uncertain?

The public often has an idealistic view of science—and of scientists. It regards scientific theory and observations as objective and value-free, and scientists as unbiased searchers for the truth—quite unlike the popular image of lawyers and politicians.

This appraisal is mistaken on several counts. Some areas of science are indeed very exact, and the theories can be relied on to produce quite accurate predictions. Planetary orbits fall into this category—with accurate predictions extending far into the future. But as spectacular as these predictions might seem, they are based on a very simple theory—Newton's gravity theory—and involve generally not more than two bodies interacting in a near vacuum. (When calculating the orbit of the Moon, for example, it is quite safe to consider only the influence of the Earth and the Sun and to neglect the gravitational effects of the other planets.)

Environmental science is not like laboratory science, where we can perform carefully controlled experiments that allow us to determine the effect of one variable while all others are held fixed. Unfortunately, environmental science invariably deals with many quite complicated interactions that are hard to disentangle. For that reason the meteorologist cannot forecast the weather very accurately—and hardly at all beyond a few days.

As the situation becomes increasingly more complicated, scientists are called upon to exercise "judgment." They must construct a "model" of the real situation, one that simplifies by neglecting "unimportant" facts and interactions and concentrates only on the "essential" ones. To use the weather example again, the meteorologist must somehow average the temperature or the wind over a certain area or over a certain time interval, because his computer is not powerful enough to handle the minute detail. Nor does he have finely detailed data: the observations come from only a few fixed stations. Even satellites have limited resolution. Small-scale phenomena, like clouds, are therefore poorly represented in such models.

A more complicated example of scientific judgment, and of bias, comes from the theory that chlorine destroys ozone in the stratosphere. Since this possibility was first suggested in 1974, scientific papers have almost exclusively concentrated on chlorofluorocarbons (CFCs) as the source of the chlorine. The contribution of other chemicals, such as the widely used solvent carbon tetrachloride, has been mentioned but never stressed. And the contribution from natural sources seems to have been entirely neglected—partly because their measurements are difficult and uncertain and thus require scientists who are willing to devote years to such research. Yet we know that volcanoes exhaust chlorine compounds into the stratosphere, and that oceanic life forms and salt spray also provide potentially important sources. The data on the time trends of chlorine and chlorine compounds in the stratosphere are not yet sufficient to resolve this issue. Despite this, the United States and other nations have embarked on an expensive program to cap and roll back production of chlorofluorocarbons, which are used in refrigerators, air conditioners, foam plastic manufacture, electronic circuit board cleaning, etc.

Direct disagreements are often based on the assumptions that underlie the analysis or the mathematical model. For example, among scientists acid rain is generally understood to present no hazards to human health. The assertions that acid rain causes lung damage are based on assumptions that persons stand outdoors for 70 years, face the wind, and inhale all that it carries—a "worst-case" and clearly unrealistic assumption. Yet worst-case assumptions are often embedded in damage analyses—sometimes in the form of protecting a particularly sensitive group of individuals. (See the article by Frederick H. Rueter and Wilbur A. Steger in this issue.)

Research Can Resolve Scientific Controversies

There are many examples of scientific controversies that were eventually resolved because of better or more complete data, or because of a better theoretical understanding. A classic case is the supersonic transport (SST) and its alleged effect on stratospheric ozone. When Congress canceled the program to construct two prototypes in March 1971, the prevailing scientific view was that water vapor from the combustion of a fleet of SSTs' engines would destroy a few percent of the ozone, admit more solar ultraviolet radiation to the Earth's surface, and thus increase somewhat the incidence of skin tumors. Within a few weeks the view changed drastically when it was discovered that nitrogen oxide (NO$_x$) pollutants were likely to be the real villain; some early estimates of ozone destruction reached as much as 70 percent. As natural sources of NO$_x$ were identified and as better laboratory measurements of the relevant stratospheric atmospheric chemical processes became available, the estimates of the effects of NO$_x$ became smaller and smaller, and by 1977 scientists agreed that a fleet of SSTs would probably *enhance* stratospheric atmospheric ozone. Yet a couple of years later, better data caused estimates to reverse again, and NO$_x$ was calculated to produce a small decrease of ozone. In the meantime, however, the chlorofluorocarbons had been identified as the most important human influence leading to possible destruction of stratospheric ozone. But by a strange coincidence it turned out that NO$_x$ would counteract to some extent the effects of chlorofluorocarbons. After all then, the SSTs may yet protect the ozone layer.

These wild gyrations of the estimated effects of NO$_x$ may not be typical. But the experience should instill a certain amount of humility in those who make confident predictions based on inadequate scientific data or models and caution in those who act upon these predictions and use them as the base for setting environmental policies.

Currently, we may be facing a similar problem in understanding the health effects of low-level nuclear radiation. We all agree that high doses of radiation will make people sick, and even kill them if the exposure is great enough. But what about the effects of long-term exposure to *low* levels of radiation? To what extent is such exposure cumulative? One view is that the cumulative dose matters—the so-called "linear hypothesis." If a dose of about 25 rem (units for measuring radiation exposure) produces physiological effects and the maximum recommended dose for exposed workers is no more than 5 rem per year, then even an additional 100 millirem per year may not be safe for the general population. (The U.S. population receives on average between 100 and 200 millirem per year, mainly from natural sources.) The postulated dangers include not only cancer, but birth defects and genetic changes. The proponents of the linear hypothesis have presented some supporting evidence, but it is not widely accepted.

On the other hand, the "threshold hypothesis" assumes that the body has certain mechanisms that repair the genetic material in the cell, provided that these mechanisms are not overloaded, that is, that the radiation level remains below a certain threshold. The proponents of this hypothesis observe, for example, that the population of Denver, exposed to a much higher level of naturally occurring cosmic radiation, shows no higher rate of cancer or other ill effects than populations in other areas of

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the United States.

This dispute, which dates back to the atmospheric nuclear bomb tests, is difficult to resolve. Direct experiments are quite impractical; the existing epidemiological evidence is inconclusive. But new data have just been collected that will either settle the dispute or, more likely, start an even greater controversy. The new data are based on measurements of radon levels in houses and on the cancer rates of people living in these houses. Radon is a naturally occurring radioactive gas, released from the ground into the basements of houses and trapped and concentrated there because of poor ventilation. In some geographic locations in the United States these levels reach many thousand times the ambient level in the open air. The "linear" advocates would expect a significant increase in cancer rate to accompany the higher radon levels. The "thresholders" would expect no significant effect. The actual data, however, suggest a reverse correlation—a *decrease* in cancer rates with higher radon levels over some range. If these counterintuitive results are independently confirmed, they would lend support to a third hypothesis that a small amount of radioactivity actually benefits human health. This hypothesis, however, has not been generally accepted—partly because of the lack of definitive data and partly because of the absence of a plausible theoretical explanation. Scientific resolution of the issue is of obvious practical importance. It affects exposure standards in all sorts of applications—from workers in nuclear plants and disposal of radioactive waste to allowable cosmic-ray exposures for aircraft crews and astronauts.

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Environmental Strategies When Science Is Uncertain

Once we accept the inevitability of some scientific uncertainty, what are the strategies available and what should one consider in choosing the optimum strategy?

I would suggest four strategies of increasing levels of action and of cost:

- *No action, not even more research.* Such a policy would be indicated if the environmental allegation is wholly implausible, such as an allegation that emissions of pollutants into the atmosphere somehow cause earthquakes or, even more farfetched, that they affect sunspots.

But what about the implied claim, in 1987, by a witness before Congress that the newly discovered Antarctic ozone hole (a localized, temporary, seasonal thinning of ozone in the lower stratospheric layer) could be linked to the incidence of melanoma skin cancers in the United States—just because both phenomena had increased in the preceding decade. In this case the implied effect is mildly plausible but clearly wrong. (The explanation here is straightforward. Melanoma incidence does not show a clear relation to long-term ultraviolet radiation exposure—unlike the incidence of the less virulent basal and squamous cell skin tumors. The time delay between exposure and incidence is usually measured in decades. Ozone decreases over the Antarctic should not increase ultraviolet radiation in the United States. Actual measurements at several U.S. locations show a clear decline in the intensity of ultraviolet radiation. Finally, researchers have observed an increase in the incidence of melanoma over the 50 years that they have collected separate statistics for melanoma—long before the recent ozone hole.) In cases where public concern has been raised, it is important to explain the phenomenon and continue monitoring, but one need not initiate research on every such weakly plausible effect.

- *More research, but no other action.* Research is the best known way to reduce scientific uncertainty and thus represents a sound component of any strategy. Research is generally much cheaper than action to control pollution. The research budget for the National Acid Precipitation Assessment Program (NAPAP) has been on the order of $600 million over a 10-year period, while action programs would have been in the $5 billion to $10 billion per year range. NAPAP has been unusually effective—changing the thinking of many scientists on what causes acid rain and on its possible ecological effects. If decision-makers pay attention to the scientific conclusions of NAPAP, they could save the nation a great deal of money that could be better spent on other environmental and social problems. (See the article by J. Laurence Kulp in this issue.)

- *Partial control, usually phased in over a period of time.* An example is the phased partial reduction of chlorofluorocarbon production, approved in the 1987 Montreal Protocol, triggered by the discovery of an Antarctic ozone hole and a public concern fed mainly by the fear of skin cancer. This action was probably premature and is not supported by adequate scientific understanding. We are still learning new facts about the mechanisms responsible for the hole and about the ultimate causes. Certainly, no one today can predict the extent, duration, and depth of the hole with any confidence.

- *Full control, often on an accelerated time scale.* An example is the more rapid and complete phaseout of chlorofluorocarbon production, suggested since 1988, after the announcement of an alleged *global* ozone decline. Again, much more research is in order before a further reduction in chlorofluorocarbon production—especially since the ozone "decline" may be only an artifact of the statistical analysis.

In choosing among these strategies, policymakers should address two important questions:

- Are the effects likely to be serious?
- Are the effects reversible?

As a general rule, local effects, like urban air pollution, are reversible—in the sense that the pollution is not cumulative. Air quality improves immediately when polluting emissions cease or when meteorological ventilation improves. Similarly, acidity cannot accumulate in the atmosphere. Because of rain-out, most chemically active pollutants remain in the troposphere no more than a few days and therefore cannot build up to high concentrations. On the other hand, some of the cumulative effects of acid rain may not be easily reversible.

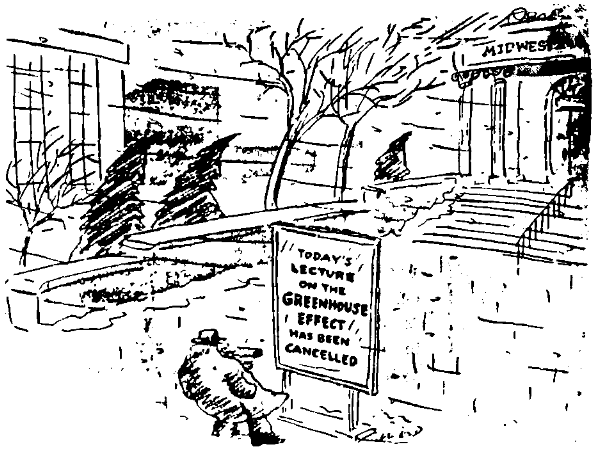
Global pollution can only be produced by substances having long atmospheric lifetimes, such as chlorofluorocarbons or the carbon dioxide (CO_2) from burning fossil fuels. Global pollution thus tends to be less reversible and at the same time potentially more serious. There is the further concern, which must be taken seriously, that the effect grows nonlinearly with increasing pollution and could even be irreversible. It has sometimes been suggested, for example, that our planet may be subject to more than one stable climatic state.

Unfortunately, scientific uncertainties about the effects of global pollution are quite large. This suggests two further questions to be jointly considered:

- What is the risk involved in postponing a decision to act? That is, how much worse might the condition become if action is delayed?
- What are the chances of gaining more scientific understanding as a result of the delay?

The acid rain issue provides a case for the benefits of delay. Instead of taking hasty action in 1980, the U.S. government started a 10-year research program that has significantly changed the scientific basis for a policy decision, not only about how to reduce the acidity of precipitation, but also about how acid rain affects lakes, forests, and crops.

The threat from global greenhouse warming is more controversial, but there is little reason to believe that this threat would become substantially greater if drastic action is postponed for several years, and the prospects of reducing scientific uncertainty during this period are excellent. In any case, the prospects of mounting quick international action to limit greenhouse gas emissions—not only of CO_2 from the burning of fossil fuels and of forests, but also of the more naturally produced methane and nitrous oxide—are daunting.



BY STAYSKAL FOR THE TAMPA TRIBUNE

My personal views on the complete phaseout of chlorofluorocarbons are similar. I am not as yet convinced that we have seen any effect of CFCs on the global ozone layer, and the theory is uncertain enough to make the degree of future changes doubtful. More science is clearly necessary before taking irreversible action. With respect to the "Antarctic ozone hole," if chlorofluorocarbons are indeed the culprit, I have argued elsewhere that the hole is now controlled by climatic conditions and that its future will not depend on CFC releases, nor would it disappear if CFC production were halted.

One final criterion should affect the choice of environmental strategies: the cost of action compared with its value as an insurance policy. A good example might be taken from the 1983 report of a White House panel on acid rain. It recommended that certain low-cost steps be taken to remove *some* of the polluting emissions forming acid rain, while continuing the research program. Low-cost steps would be facilitated by amending existing legislation to permit emissions trading on a wider basis than the emissions offset or "bubble" approach now allowed. (See the article by Gordon L. Brady, Michael T. Maloney, and Alden F. Abbott in this issue.)

In cases, therefore, in which the asserted environmental effect is plausible, costly to reverse, and serious, there is a good argument for taking some low-cost steps, even if the scientific evidence is not compelling—on the theory of prudent insurance. The problem then becomes how far to take such measures—how much insurance to buy. Scientists can clarify this issue, but politicians must resolve it.

Selected Readings

Singer, S.F., ed. *Global Climate Change: Human and Natural Influences.* New York: Paragon House, 1989.

Wildavsky, A. *Searching for Safety.* New Brunswick, N.J.: Transactions Publishers, 1988.

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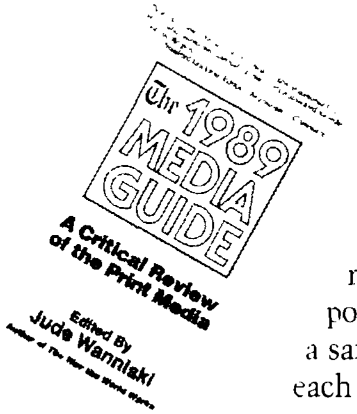

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