Kates, R. W., 1977. "Assessing the Assessors: The Art and Ideology of Risk Assessment", Ambio, Vol. VI, No. 5, pp. 247-252.

Assessing the Assessors: The Art and Ideology of Risk Assessment

BY ROBERT W KATES

Over the last few decades, the environment has been perceived as increasingly hazardous by the public, the media and science. Risk assessment, which developed in response, involves the identification of hazard, the estimation of the risk it poses, and the social evaluation of its meaning and importance. The author notes that in practice, risk assessment is still more art than science.

Human beings appear to become increasingly adept at creating, discovering or rediscovering threats to themselves and to their environment. A new professional interest, risk assessment, has developed in assessing these hazards. Risk assessors are becoming more numerous and their products in the form of risk assessments, benefit-risk analyses, environmental impact statements, and technology assessments are widely diffused.

The task is not one for specialists alone; people have always assessed environmental threat: storm, drought, fire or disease. But for the new and newly-discovered hazards, there is high perception of risk but little experience with consequences. With such uncertainty it is not surprising that risk assessment practice is still more art than science and that distinctive, contrasting ideologies flourish.

THE MORE HAZARDOUS ENVIRONMENT

By asking people, reading newspapers or magazines, or perusing scientific journals, the environment has become demonstrably more hazardous over the last 25 years. In 1964, environmental concerns were not even recorded among the top "worries" of Americans: a decade later they have been steadily noted among the top half or third of surveyed concerns (1, 2). A detailed search of media for public "alarms" over technology during the past 28 years finds a steadily rising concern, with 60 percent of the cases appearing in the last five years of the study (3). A 27-year review of the leading interdisciplinary scientific journals of the United States (*Science*) and the United Kingdom (*Nature*) shows that research dealing with man-made environmental hazard doubled in the first fifteen years studied and doubled again in the last decade (4). By 1971, 6.7 percent of the "Letters" (spontaneous scientific reports) in *Nature* and 4.0 percent of the "Research Reports" in *Science* presented findings related to environmental threat.

Overall, while these examples of public and scientific interest fluctuate with peaks of crisis concern or with competitive worries over the economy, war, or violence, they have increased by factors of three to six (see Figure 1). Yet if the statistical indications of consequences are examined–data on mortality and morbidity, property damage, and negative social indicators—no similar increase is recorded. The dramatic increase in perception seems to be in anticipation of rather than in response to a marked deterioration of the security of life.

The life expectancy of people rises—rapidly in poor nations through increased survival of the young, slowly in rich nations pressing on a ceiling of medical, life and environmental understanding. In the wealthy world people live longer today than fifty years ago, die less of infectious disease, and more of stress, diet and malignancy. Cars kill them more frequently than in the past, but other accidents less; the balance is in their favor. Overall, the newly-discovered hazards of the man-made environment, while they offer much recent concern, are too new to measure their consequences in the statistical yearbook.

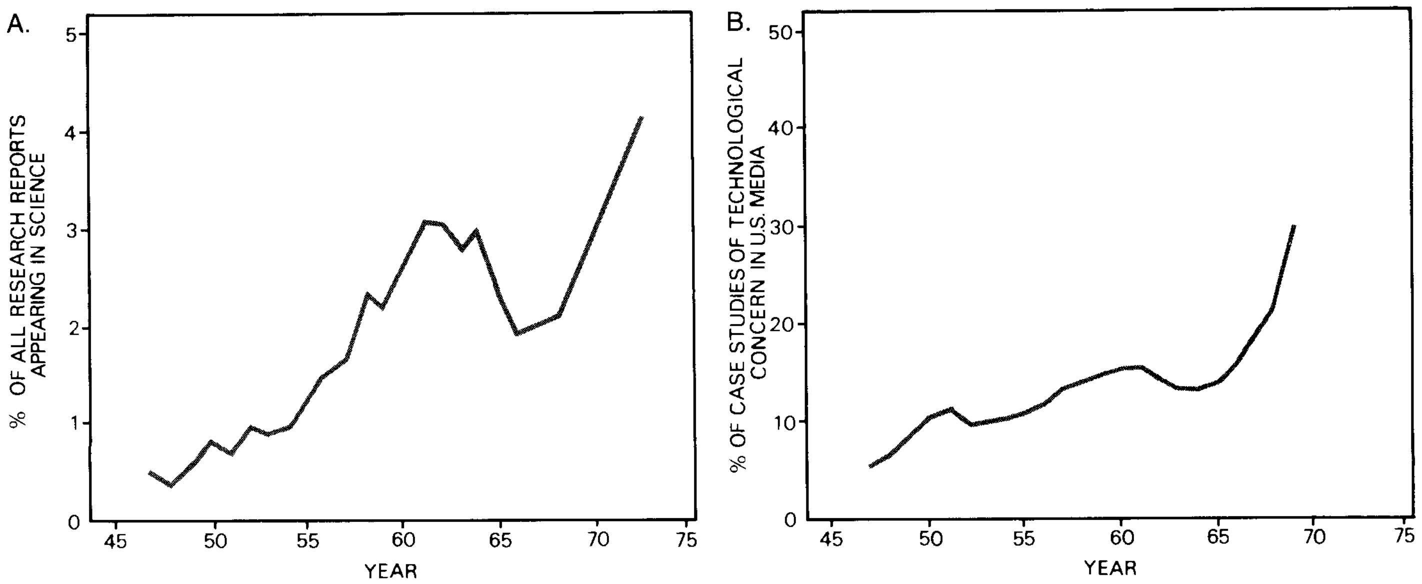


Figure 1. Trends in scientific research, media and public opinion. A. Scientific Research is based on analysis of research reports appearing in the interdisciplinary journal *Science* (4). B. Public Alarm over Technology is based on a 5-year running average of 45 case studies of alarm as evidenced by major newspapers and periodicals (3). C. Public Opinion is based on rankings of between 20–30 worries and concerns from repeated nation-wide US opinion polls. In 1964 no environmental concerns were deemed important enough to list.

RISK ASSESSMENT METHODS

Filling the gap between the perception of hazard and the experience of harmful consequences is the developing methodology of risk assessment (5, 6, 7, 8, 9). The overall process can be separated for descriptive convenience into three overlapping elements (Figure 2), with the recognition that in practice the distinctions are considerably blurred. *Hazard identification* is the recognition of a hazard, the answer to the question: what constitutes a threat? Its methods are the methods of research, and of screening, monitoring and diagnosis. *Risk estimation* is the measurement of the threat potential of the hazard, an answer to the questions: how great are the consequences, how often do they occur? Its methods are methods of knowing: revelation, intuition and extrapolation from experience. *Social evaluation* is the meaning of the measurement of threat potential, an answer to the question: how important is the estimated risk? Its methods are methods of comparison: aversion, balance and benefit-cost analysis.

Hazard Identification For much of human history, the identification of environmental hazards arose from the direct human experience of harmful events and consequences or from the application of ritual or magic. For the last hundred years, and for the future, the identification of new and newly-discovered hazards will depend for the most part on science.

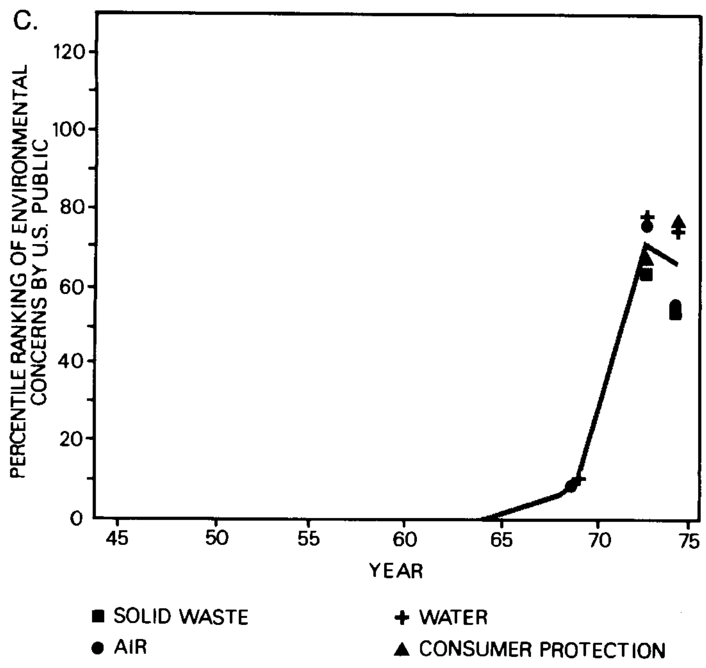
Basic research or "pure science" is not directed toward risk assessment; it deals with knowledge for its own sake. Nevertheless fundamental scientific inquiry discovers threats, albeit somewhat randomly, and provides the basis for directing and interpreting more purposeful search. "Critical" science (10) engages in a purposive, intensive search for environmental hazard as part of its effort to redress the perceived imbalance between technology and the human environment. But the institutionalized task of hazard identification falls to "practical" or "applied" science, employing screening, monitoring and diagnosis.

In *screening,* a standardized procedure is applied to classify products, processes, phenomena or persons for their hazard potential (11), while *monitoring* (in health studies, surveillance) observes, records and analyzes the same for the recurrence of hazardous events or their consequences (12, 13). In *diagnosis,* the identification of hazards takes place through analysis of indicators or symptoms of consequences (14, 15). Each of these methods has distinctive historical origins and preferred usage in certain disciplines and professions, and only now, in the context of Earthwatch activities (16), is there emerging some searching comparison of these methodologies.

Implicit in these methods of hazard identification is a sequence in the suspectability of hazard potential. Screening procedures are akin to "fishing expeditions". Monitoring implies knowledge of threat potential, where the purpose of monitoring is to measure variation in some critical indicator, the cumulation of a hazardous condition, or the failure of a protective device. Diagnosis implies the ready existence of hazard-indicative "symptoms", some abnormal set of events or consequences, the location, etiology or treatment of which is in doubt.

In any complex socio-environmental problem, almost all the methods of hazard identification are called upon. A current example might be the recent and growing discovery of threats to the atmospheric ozone column which serves to protect us from ultraviolet radiation and resultant skin cancer.

The basic chemistry of ozone formation and its observed concentration in the stratosphere dates back to



Chapman's work in 1930 (17). But it was only in the context of the US debate over development of suspersonic transport (SST) that the hazard became identified. In 1971, James Mc Donald, an atmospheric scientist with an interest in public policy issues, connected the distribution of skin cancer with latitudinal variation in ozone (18). His favored mechanism for ozone destruction was water vapor injection from the SST. In this he erred, overestimating the effect. Crutzen and Johnston, drawing on their basic research, identified NO_x as the major catalyst with ozone destruction potential injected by SSTs into the atmosphere (19, 20). An applied governmental research program, the Climatic Impact Assessment Program (21) has now validated most of these early hypotheses at a cost of US$20 million.

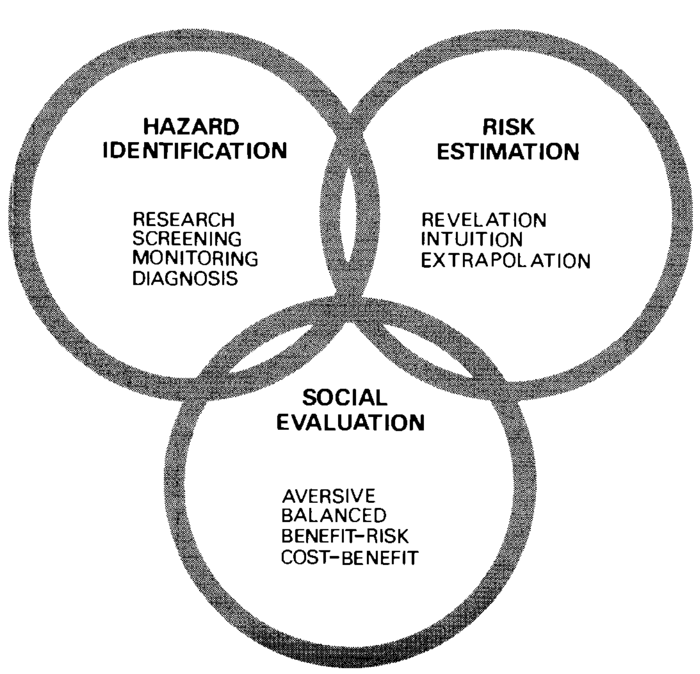


Figure 2. Risk assessment elements. Risk assessment is composed of three overlapping elements. Hazard identification is the recognition of risk; estimation is the measurement of its threat potential; and social evaluation, the appraisal of its meaning and importance.

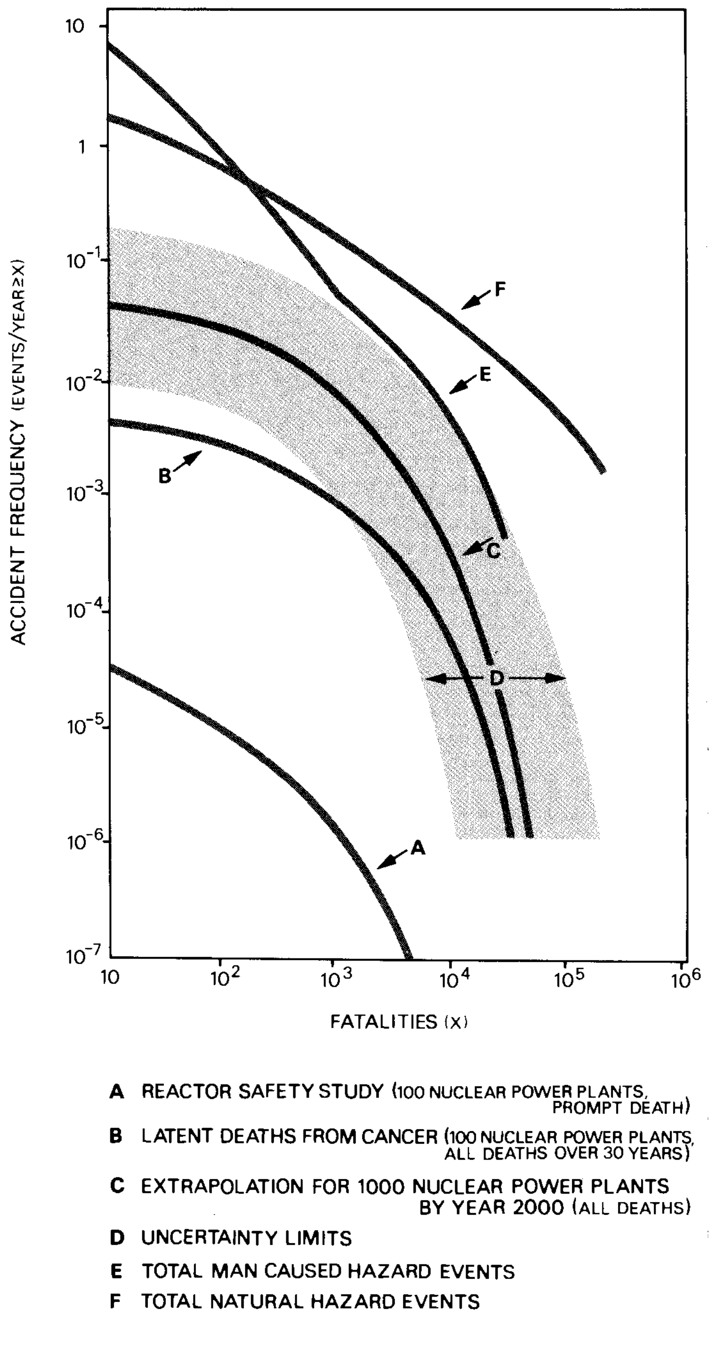
Once the search began for mechanisms of ozone destruction, basic knowledge of chemical reactions suggested other sources of minor catalytic species. These now include the chlorofluorocarbons in aerosol cans and refrigeration, atomic warfare, the space shuttle, and nitrogen fertilizer. Finally, new monitoring efforts have been pursued to measure ozone and its various destructive catalysts and for the surveillance and analysis of skin cancer incidence.

There are various problems with all efforts at hazard identification: problems of reliability (serious hazards do not get identified), of cost (collecting large amounts of expensive data little used or of little use), and of bias (the data are misleading in some consistent way). The most serious problem, however, is the proliferation of unknown hazards. It seems unlikely that random research thrusts, underfinanced critical science, or massive screening, monitoring and diagnostic methods can keep pace with the creation of environmental threat. It is sobering to note that just three years ago, atmospheric scientists had proposed monitoring a commercial chlorofluorocarbon, not because of its hazard potential, but because it was deemed an inert non-reactive tracer!

Risk Estimation Revelation of the likelihood of threatening events and their consequences by divine or supernatural inspiration is as old as the sacred prophetic religious experiences or as common as the astrology column of the newspaper (22). Its value clearly depends on the degree of belief and number of believers. Intuition shares some qualities with revelation, but is internally generated and is employed in both science and everyday experience (23).

Scientific risk estimation for the most part rests on extrapolation: forward from past experience; backwards from unknown but imagined events to their known precursors; or sideways by analog and transfer of experience from different but similar places, situations, or things. A great deal of ingenuity has gone into refining methods of extrapolation: improving the underlying data base (24), clarifying the meaning of probability (25), developing more precise and powerful mathematical methods (26), creating tree-like logical sequences of events and consequences (27), modeling systems (28), quantifying subjective estimates (29, 30), and stretching imagination by scenarios (31). All such methods are hampered by common and sometimes subtle distortions of assumptions and method (32) and by the limits of human cognitive processes (33, 34). But most difficult is the "prison of experience" — humans are at risk from threats greater than or different from individual and collective experience (35). And extrapolative methods, no matter how ingenious, can only enlarge but not escape such containment.

Figure 3. Risk of death from US commercial nuclear power reactors. The Risk Spectrum is a graph which relates the frequency and magnitude of a catastrophic nuclear accident. Spectrum A is the one displayed in the summary of the Reactor Safety Study and it applies to prompt fatalities only. In this widely reproduced graph, the risk of a nuclear power plant is below comparable risks of man-made and natural events by many orders of magnitude. Using the data provided in the Reactor Safety Study, it is possible to reduce this apparent margin of safety by: 1) adding in the latent deaths that will occur from radiation-induced cancer over a 30-year period (Spectrum B). 2) extrapolating to 1000 nuclear reactors by the year 2000; a target of US energy policy (Spectrum C) and 3) adding to that extrapolation the uncertainty limits of the Reactor Safety Study (Spectrum D). Extending the spectrum in this manner is a matter of judgment or bias, not of factual disagreement.



A REACTOR SAFETY STUDY (100 NUCLEAR POWER PLANTS, PROMPT DEATH)
B LATENT DEATHS FROM CANCER (100 NUCLEAR POWER PLANTS, ALL DEATHS OVER 30 YEARS)
C EXTRAPOLATION FOR 1000 NUCLEAR POWER PLANTS BY YEAR 2000 (ALL DEATHS)
D UNCERTAINTY LIMITS
E TOTAL MAN CAUSED HAZARD EVENTS
F TOTAL NATURAL HAZARD EVENTS

The ingenuity and limitations of such extrapolative methods are well exemplified in the *Reactor Safety Study* (27) prepared for the US Atomic Energy Commission in 1974 by Professor Norman Rasmussen of MIT. A landmark in the art of risk estimation, the study nevertheless requires a degree of belief in the hypothetical (36), because in the 300 years of commercial power reactor operation there has never been a catastrophic accident or even a catastrophic accident-initiating event. Thus the study and its users needs to rely on varied substitutes for experience: logical analysis, understanding of physical laws, frequencies of component failures, and radiation dose-response curves derived from studies of animals and war victims. Using these in combination, it is possible to estimate the risk spectrum for a catastrophic event as shown in Figure 3. But unlike the man-caused and natural events to which these risks are compared, nuclear power consequences have not been experienced. Indeed, the very complexity of the risk estimation process weakens its credibility. And even for those willing to suspend skepticism in the methods and to rely on the data of the *Reactor Safety Study,* very differing interpretations of the data are possible, as shown in Figure 3.

Social Evaluation In the aversion of hazard or of risk itself, little or no consideration is given to comparison with other risks and benefits. Aversive methods are embedded in culture as taboos, in society as absolute standards or regulations, and in people as avoidance preferences. Aversion as taboo may be considered "primitive", while as a regulatory standard (*eg* zero tolerance for carcinogens in food) it may be considered modern and indeed scientific, but the logic of its method is difficult to infer (37).

In contrast to the absolutes and imperatives of aversion, balanced risk methods seek to compare and equalize consequences. Frequencies of mortality, morbidity or damage are compared in order to encourage some action or to reveal some inconsistency (38). Risks can also be compared to their costs of avoidance as in cost-effectiveness studies (6), to their benefits, as in benefit-risk analyses, or in some overall benefit-cost analysis. Again much ingenious effort has gone into improving the data base for comparisons (39), to seek revealed societal preferences for acceptable levels of risk (40, 41), to illuminate inconsistencies between different accepted risks and between different communities and nations (42, 43), to compare benefits and costs which have multiple attributes (44, 45), and to improve the making of judgments (46, 47, 48). These comparisons are limited by the data base but more importantly by differences in distribution of costs, risks and benefits.

Immediate benefits need to be compared to uncertain, amorphous or long-term costs, or widely diffused benefits compared to risks falling heavily on a specific population or place. And hazards with low probabilities of occurrence but catastrophic consequences need to be compared to hazards of higher probability but less serious consequences.

Thus in the examples previously given, the social utility of the Concorde and of future SSTs, the convenience of aerosol sprays, and perhaps even the production of food (using nitrogen fertilizer) will have to be weighed against uncertain estimates of increase in skin cancer. And the risks of coal-produced electricity—the exacerbation of respiratory disease and increases in premature deaths for the exposed public, black-lung disease and accidents among miners—need to be compared to nuclear hazards of rare occurrence and latent effect. Consensually accepted methods for making such comparisons are not available.

RISK ASSESSMENT IDEOLOGY

The perception of hazard is high, the facts of risk are ambiguous, the methods of analysis are limited and still in development. It is not surprising, then, that hope, fear, and faith enter the risk assessment process as overriding views or assumptions that in archetypal expression border on ideology. Each assumes a fundamental imbalance between prevailing risk assessments and their hazard potential. Each begins with the implicit assumption that the true hazard potential is greater than, less than, or different from, the prevailing risk assessment.

Tip of the Iceberg For some risk assessors, the hazard is almost always greater than the risks assessed. For them, the consequences of technology are too recent to be apparent; only the tip of the iceberg is assessed.

> The role of casualties of our time is incomplete. Among those numbered in hundreds every year we have counted invalid survivors of spina bifida, patients accidentally injured during cardiac catheterization, and those disabled by reactions to such drugs as chloramphenicol. Rising casualties numbering thousands annually result from the health environment surrounding certain infants born in our cities, from the vulnerability of young people to head injuries, drug addiction, and crime, and from chronic lung disease associated with air pollution. Increasing numbers, in the tens of thousands every year, suffer or die from arteriosclerotic heart disease or are disabled by the frailties of age. Other casualties may be on the way: additional victims of environmental pollution, more infants surviving with genetic defects, more casualties of affluence, made useless by automation or retired from boring work, more artificially supported survivors, and more casualties of new drugs. Though these numbers may in a sense be outweighed by a rising standard of living, better education, less work, and less discomfort, they are surely enough to cause concern (49).

For them, by the time the roll of casualties is complete, it is already too late; such are the latent effects of carcinogens or mutagens.

The basic methods of "tip of the iceberg" assessors complement their concern. They search for new hazards, try to estimate consequences, particularly from maximum events, and to predict long-term effects. At the same time they avoid estimating the probability of events leading to harmful consequences, arguing that in the absence of adequate experience these will tend to be underestimates. Their favored method is the use of the scenario because it stretches the imagination, makes the incredible more credible, and suggests the greater hazard lurking beneath seas of complacency.

Count the Bodies For some risk assessors, the hazard is almost always less than the risks assessed. Because of scientific and technical advance, administrative oversight, and the long-term increase in societal ability to cope with threat, people are demonstratively better protected. If the environment appears less secure to many, it is because of changes in social expectations, certain processes of communication, and recurrent waves of public fad or mood.

Social values and expectations of security change, becoming more demanding over time, as evidenced in movements for consumer, environmental, and occupational safety. The dramatic increase in communication leads to exaggerated assessments. Improved reporting of events previously unreported creates an illusion of their increase and of global threat for what may be highly localized problems. And these trends may overlap with secular or cyclical changes in attitudes. Recurrent waves of pessimism are thought to alternate with periods of optimism, especially among intellectuals and elites. The populace, and especially youth, is currently seen as suspicious of authority, hostile to science, and attracted by irrationality. The public is viewed as ill-informed, depersonalized and frustrated by the bigness, complexity and remoteness of phenomena that impact on its life.

These assessors see themselves as struggling for fact, caution and rationality, to "count the bodies", not the speculations. Thus they tend to limit themselves to short-run consequences, arguing that these are reasonably knowable. In estimation, they favor quantifying the likelihood of events (usually small) and to compare these to the likelihood (usually higher) of everyday hazards seemingly acceptable to society. Their favored methods is quantification by reduction, extrapolating from unknown to known events. This fault-tree and event-tree methodology emphasizes the contingent nature of catastrophic hazard and its ensuing low probability.

Worry Beads Finally, for some risk assessors the major hazards are different than those for which risks have been assessed. They accept the insights of those who assert that the visible risks assessed are but the tip of the iceberg as well as those of the skeptical statistician, technologist or social commentator who knows that many perceived threats will on hindsight be shown to be exaggerated. Their concern is that the societal ability to assess risk is limited, expandable but not infinite, and in danger of being squandered on the unimportant while failing to identify the truly perilous.

Stated as the "worry bead" hypothesis, individuals and societies have a small, relatively fixed stock of worry beads to dispense on the myriad threats of the world. They are not irrational, but are constrained in their rationality either by human limitations of cognition and judgment; by cultural, ideological or personal aversions toward certain risks and the discounting of others; by ignorance, misunderstanding or limited experience; or by the sheer number and complexity of threats to cope with. The societal capacity to worry intellligently exceeds that of individuals and it is possible to divide the labor and the anxiety. But even this expanded capacity, in this view, is less than the threats perceived, and to both individuals and societies, where and when to rub one's worry beads is baffling and difficult to rationalize even if desired.

Thus "worry bead" assessors first strive to improve overall strategies of hazard identification. In examining evaluation methods, they study empirically the societal response to threat to determine "what is", not simply "what ought to be". Their favored methods are those designed for improving and making easier decision and choice, and for allocating the appropriate institutional mechanisms and group processes to the "right" type of hazard.

LIVING WITH IDEOLOGY

In individual risk assessors, these archetypes of ideological risk assessment are clearly overdrawn and individuals display a mix of attitudes. Yet the typology can be readily applied and this has been done in the case of nuclear power (9). As representative approaches, they are not easily displaced. Such is the nature of the environmental hazard problem.

The review by Lawless of 45 major public alarms over technology found that in over a fourth of the cases, the threat was not as great as originally described by opponents of the technology, but in over half of the cases, the threat was probably greater than admitted by the proponents of the technology and the problem was allowed to grow. Early warning signs were available and mostly ignored in 40 percent of the cases, and technology assessments (which usually include a risk assessment), had they been done, were judged by the study team as surely helpful in only about 40 percent of the cases (3).

As the theory and methodology of risk assessment evolves and improves, there is hope for greater scientific consensus as to what is known about the hazards assessed (50), what needs to be known and how to learn it (51), and what the limits of knowing are (52). But it is highly improbable that even improved procedures of hazard identification, risk estimation and social evaluation can cope with the proliferation of threat. The burden of hazard needs to be reduced, not because many serious risks cannot be assessed and coped with, but because all of them cannot be.

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53. The work on which this paper is based has been supported by a United Nations Environmental Program grant to the International Council of Scientific Unions, Scientific Committee on Problems of the Environment, Mid-Term Project No. 7, "Communication of Environmental Information and Societal Assessment and Response," and by the Electric Power Research Institute for the Workshop on Comparative Risk Assessment of Environmental Hazards in an International Context, held in Woods Hole, Massachusetts from March 31 to April 4, 1975. In its preparation I have been greatly assisted by Mimi Berberian of Clark University.

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