RATIONALITY AND IRRATIONALITY IN ESTIMATING THE RISKS OF NUCLEAR WASTE DISPOSAL

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ABSTRACT

In addition to their intrinsic or "academic" interest, public perceptions of risks have begun to receive increased scientific attention for at least three reasons that are directly relevant to waste disposal. The first and most commonly recognized reason is that, if people perceive a problem to be real, it will be real in its consequences. This means that unless public perceptions are taken explicitly into account, decisionmaking will be based on inaccurate information, and the impacts of developments will not be properly understood, predicted, or mitigated. The second reason is that, now that perceptions are beginning to be the focus of increased scientific inquiry, the nature of public perceptions is beginning to be better understood. It is becoming clear that it is not accurate to characterize public perceptions as being simply unpredictable or "irrational," and studies are making considerable progress in documenting the factors that tend to influence public perceptions of facilities such as nuclear waste repositories. Third, increasing evidence indicates that the real-versus-perceived distinction is not as clear as was once assumed, and for two reasons. One reason is that, while expert judgments are often as taken as representing "real" risks for decisionmaking purposes, it is impossible to know the "real" risks of technologies for which little or no actual operating experience has accumulated, and expert judgments often prove under closer scrutiny to express the scientists' values as well as science's facts. The other reason is that the broader public's perceptions now appear to reflect more wisdom than was at first apparent. Indeed, rather than perceiving the public as irrational, we may need to consider a newer conception of the public as prudent, exercising many of the same kinds of judgment and oversight responsibilities as would be found on a Board or Trustees or Board of Directors.

For several decades, the nuclear waste issue has been the subject of extensive research in a variety of scientific fields, particularly in the geophysical sciences. In recent years, however, it has become increasingly clear that many of the most serious problems of nuclear waste disposal are likely to be found not below the ground, but on it. They have to do not so much with the rock bodies beneath the surface as with the human ones on top (1, 2, 3).

Despite this fact, however, there is still a curious bifurcation in our national approach to the problems involved in nuclear waste disposal. The geophysical issues have been described as "research" questions, and they have been the focus of many millions of dollars' worth of concentrated scientific attention. The sociopolitical issues have been described as "management" questions, and they have scarcely been researched at all.

It is becoming increasingly clear, however, that this imbalance is both unnecessary and ill-advised. First, there is no law of nature that requires us to abandon the use of the scientific method merely because questions of human behavior are involved. Second, many if not most of the sociopolitical issues involved in nuclear waste disposal are in fact researchable, empirical questions. They are questions that can be answered on the basis of evidence, rather than assertion--but only if the relevant evidence is made available.

This is true even with what may be the most difficult issues of all--and certainly some of the most controversial--the public perceptions of the risks that might be associated with a high-level nuclear waste repository. As Paul Slovic, Roger Kasperson and their colleagues have pointed out elsewhere in this volume, the public clearly sees a repository in involving a higher level of risks than do members of the technical community (see also (4)). One of the conclusions that can be drawn from this observation--a conclusion that has in fact been heard a number of times at the Waste Management '87 Symposium--is that members of the general public are either ill-informed or irrational. If they are ill-informed, the reasoning goes, then they should be educated on the "true facts" about repository development. If they are irrational, then they may simply be beyond the reach of educational programs. In either case, the implication would seem to be that public perceptions are not the sorts of factors that can or should be taken into consideration in the making of repository-related decisions.

This paper will offer a different view. There is no law of nature that requires us to abandon the use of the scientific method merely because questions of human behavior are involved; indeed, given the increasing evidence on the importance of public reactions for the repository siting issue--along with the fact that the repository-related decisions are being made in a democracy--I will argue that we should expect analyses of public perceptions that are no less thorough, no less extensive, and in a word, no less scientific, than are the analyses we expect to see in the geophysical realm. On closer scrutiny, moreover, the public reactions on nuclear issues may prove to be far less "irrational" than is sometimes assumed.

For those of you who are scientists, your own commitment to the principle of systematic analysis may be sufficient for you to acknowledge the legitimacy of undertaking a closer and more detailed study of public perceptions. But for those of you who take a pragmatic or policy-oriented view, the esoteric suggestion that

we do scientific research for its own sake may not be sufficient. Accordingly, I will use the rest of my paper to sketch out three reasons for attention to public perceptions that are less esoteric and more pragmatic. They are also likely to be more controversial. I will deal with them in order of increasing controversy, and with one key request: I ask that you make every effort to consider these remarks with the same kind of scientific detachment that you would attempt to maintain for any other question related to the development of a nuclear waste repository.

The three points are as follows. First, it is impossible to perform an adequate assessment of the socioeconomic impacts of a nuclear waste repository without explicitly considering the public's perceptions of risk, since the actual socioeconomic impacts will depend on "the facts" that actually get through to the public, not merely those that are believed in agencies and in the technical community. Second, even if the public assessments and the expert assessments of the risks are found to differ, we need to realize that what appear to be "scientific" statements about nuclear waste respository development may actually contain significant value judgments, not just "facts." And third, the purportedly "irrational" concerns of the public may at times reflect more wisdom than is at first apparent. The remainder of this paper will deal with each of these three points in turn.

<u>The actual socioeconomic impacts of a nuclear waste repository will depend on "the facts" that actually get through to the public, not merely those that are believed in agencies and in the technical community.</u>

This is the least controversial of this paper's three points, and thus it will be dealt with in the least detail. The point is also quite straightforward. We are required--both by the Nuclear Waste Policy Act and by other relevant regulations, such as the National Environmental Policy Act--to devote explicit attention to the socioeconomic impacts as well as the environmental impacts of repository development. The assessments of socioeconomic impacts will need to meet at least the normal standards of scientific adequacy, and it is well-known in the social sciences that, if people perceive a situation to be real, it will be real in its consequences. The net result is that any study that fails to devote explicit attention to the actual public perceptions can be virtually guaranteed of reaching unscientific, systematically erroneous conclusions.

But it is not merely a matter of studying public perceptions "even if they are irrational." We also need to realize that, while it is fashionable to talk of the differences between "perceived risks" and "real risks," the distinction may not be as clear as sometimes assumed. The second and third points of this paper both have to do with this supposed dichotomy.

<u>A number of "scientific" statements may actually contain value judgments, not just facts.</u>

Perhaps the easiest way to illustrate this point is by way of an example. What follows below is a direct quote from a scientist who attended a public workshop in the Hanford area of Washington State in the spring of 1986. He spoke immediately after listening to a critic of the efforts to place a repository in Washington State, a critic with whom he clearly did not agree. His comments, however, have been selected not as an example of hostile or intemperate reactions, but precisely because he spoke with a moderate tone and with what I judge to have been a clear effort to be fair and balanced. His comments were as follows:

> "You have to be reasonable. Nothing is perfectly safe; you can't get the kind of absolute guarantee you seem to be looking for. If you'd look at the facts more rationally, you'd see that nuclear power is far safer than coal-fired power plants. Since America needs the power, somebody's got to take the waste, and this may be the best place for it. I live here, too, and I'd be trying to stop this thing if I didn't have confidence that we'd be able to take care of any problems that might arise. The real danger we face isn't the nuclear waste--it's this NIMBY syndrome. Everybody's saying 'not in my backyard.' That's just irresponsible. If it keeps up, it'll bring progress to a standstill in this country."

While this gentleman was reasonable and articulate, and while he presumably believed that he was attempting to speak against value judgments rather than making them, a closer examination reveals that, in fact, even this brief comment reflects at least seven value judgments.

First, he asserted that the previous speaker "needed" to be "reasonable." While such an assertion seems "reasonable" enough, in point of fact it is an assertion that the previous speaker should have used a weighting of decision factors with which the scientist would have agreed. It also ignores the possibility that the previous speaker might would not have stated his concerns if he thought they were "unreasonable." In fact, the previous speaker did later respond that he felt what was unreasonable was not his own effort to minimize the risks from a development he opposed, but this scientist's willingness to accept "even a small risk" of a "potentially catastrophic accident from an unproven technology." His tone of voice was not as restrained as that of the scientist, yet his point may have been no less valid. He was focusing primarily on the potential <u>consequences</u> of an accident, while the scientist was focusing primarily on <u>probabilities</u>, but this does not allow us to conclude that one was right while the other was wrong. When one is comparing decision factors that are as dissimilar as apples, oranges, and orangutans, there is literally no scientific basis for determining whether or not one factor "ought" to be given more weight than another.

In fact, the only way to make such determinations is on the basis of values. Scientists might tend to agree with one another that one set of values (e.g., efficiency) are more important than others (e.g., unknown problems that may not even surface for a century or more), and the public as a whole might tend to hold a different hierarchy of values. Even if this were the case, however, it could no more be taken as implying that it is "correct" to make decisions based on the values of the scientific community than as meaning we should base our decisions strictly on the views of the community at large. To draw such a conclusion, in fact, would be to go far beyond the scientist's generally accepted focus on "what is" and to argue instead for what, in the scientist's view, "ought" to be the case. While

scientists may have strong feelings on the "proper" weight to be assigned to various factors, the strength of a feeling may not be a reliable sign of its accuracy--a fact that scientists, of all people, presumably would be quick to recognize.

The nature and extent of this scientist's value judgments can also be illustrated with the other half dozen value-based assertions contained in his one brief comment. The second of them had to do with the relative safety of nuclear and coal-generated electricity. While it is unquestionably true in a statistical sense that the generation of electricity with coal is associated with far more deaths in an average year than is the generation of electricity with nuclear power--an association that remains true even after Chernobyl--it is impossible to "prove" scientifically that it is "better" to judge a technology in terms of its statistical average number of deaths per year than in terms of the potential severity of unlikely but plausible events. It does appear that scientists are inclined, in general, to judge technologies in terms of their statistical or "average" risks, while many members of the general public are more inclined to show concern about potentially catastrophic risks, but it does not therefore follow that scientist's judgments are reasonable while those of the general public are not, just as it does not follow that public concerns are reasonable and that scientists' are not. The two approaches are simply, if deeply, different.

The scientist's third value judgment was that the country "needs" the power, presumably in the form of electricity, that is provided at present predominantly by coal, hydropower and nuclear power. While electricity is both useful and valuable, the national "need" for it is socially and culturally defined--a reflection of values--rather than being an absolute or given "fact." Even if one argues that one is attempting to accept society as it is rather than trying to change it, this is a value-based decision, not a scientific one.

Fourth, the conclusion that a given location might be the "best place" for wastes implies not one but a series of judgments on identifying the relevant criteria for selecting a repository site and arriving at a proper weighting among them. The "best site" in terms of minimizing the transportation of radioactive materials may be very different from the "best site" in terms of minimizing tectonic activity, isolating the wastes from groundwater flows, or minimizing socioeconomic impacts. Each of these categories of decisions on "best sites," in turn, results from a series of other value judgments and weightings. To claim that one has identified "the" best site is therefore to claim not that one is being value-free, but rather that one has dealt with literally hundreds of value judgments along the way.

Fifth, this scientist indicated that he had sufficient confidence in the waste disposal technology to be willing to support its implementation near his own home. While his method of reaching this decision was probably reasonable in light of his own values, any person's "confidence" in a given technology is by definition a measure of faith and judgment, not just scientific proof. The fact that one reasonable person finds a given technology to provide a sufficient level of confidence does not mean that another reasonable person might not reach a different conclusion by using criteria that are equally reasonable, but different.

The sixth value judgment has to do with his conclusion that "the real danger" had to do with the "NIMBY syndrome." While it is not difficult to understand this scientist's frustration with what he obviously perceived to have been "obstructionist" behavior, neither should it be difficult to understand other citizens' opposition to developments that they see as threatening their safety or well-being. Perhaps the simplest way to illustrate this point is by contrasting the scientist's reaction against the reaction that might be expected from a person holding different values. One such example is provided by a person at another hearing who celebrated the very types of "responsible" citizens being criticized by the scientist. That person instead bemoaned what he called the "apathetic, it-can't-happen-here" approach being taken by the persons who did <u>not</u> oppose the idea of a nearby waste respository.

Who is right, the scientist or the community activist? In a way, both are, and yet neither is. While it is possible to be "right" or "wrong" about a strictly factual question, such as the quantity of waste currently stored at a site or the number of people living within a ten-mile radius of a facility, it is not possible to say responsibly that one set of values are inherently superior to another. Both the scientist and the community activist are to be commended for attempting to articulate the outcomes they desire, but both are on equally shaky ground in applying disparaging labels such as "NIMBY syndrome" (or "apathetic") to persons who merely prioritize the world differently.

The seventh value judgment in the scientist's short comment was expressed in his concern that "obstructionist" behavior could "mean the end of progress" in the country. The notion of "progress" is generally seen as implying an improving situation; by definition, we judge what constitutes an improving or worsening situation in terms of our values. Aside from the relatively simple (but valid) observation that many citizens see a trend toward a technologically complex society as being anything but desirable, attention also needs to be drawn to a point that is far less commonly recognized. In many if not most cases of protest against technological developments, the characteristics of development that inspire protest tend to be those that are seen as undesirable even by people who are generally supportive of technology--characteristics such as pollution, noise, risks, and other "externalities." As Jane Jacobs noted several decades ago (5), it might be more accurate to speak of problems being created not by progress, but by stagnation--by <u>inadequate</u> progress--in our technical thinking. The problem is not so much that we have developed highly complex technical and industrial systems, but that we have not yet learned how to do so without at the same time creating substantial problems, such as pollution, waste, community disruption, and so on. From a different but equally valid point of view, in other words, the question is not so much "how can we get a community to accept a potentially hazardous facility?" as it is "how can we develop technologies that provide us with the benefits of our current approaches, but that do so with fewer negative externalities?"

As should be clear by now, even when one examines the views of a moderate and reasonable spokesman for the "scientific" world view, there can be a large difference between a scientist's views and a scientific view. Indeed, the views commonly seen as "scientific" actually include a significant number of value judgments as well as factual observations. Differing value judgments, moreover, can lead to dramatically different approaches to energy development and other forms of technology, and there is an increasing body of evidence that differences in values are far more important in people's attitudinal assessments toward complex technologies than are differences in knowledge or information (6, 7).

In some ways, the "irrational concerns" of the public may reflect more wisdom than is at first apparent.

As a general rule, discussions about the broader public in a waste management context tend to follow either of two sets of implicit assumptions. Either the public is treated as being economically rational--as opposing nearby facilities unless the benefits can be shown, in a relatively straightforward economic calculation, to outweigh the risks--or else as being ignorant or irrational, opposing nearby facilities in essentially all cases, having minds made up and not wanting to be confused by the facts. What I would like to have you consider is a third and very different way of looking at the issue--a view of the public as prudent.

To put it in context, I'd like to ask you to think for a moment not about the large number of people who make up the general public, but about the small number of highly selected people who make up Boards of Trustees and Boards of Directors. What do we expect--and what do we not expect--from our Trustees and Directors? For one thing, we expect not to find too many of them in attendance at the technical sessions of a gathering such as Waste Management '87. The job of a Trustee is to establish policy, not to be involved in the day-to-day details of implementing it; experts on organizations tend to get quite concerned if they see signs that the top-level policymakers are paying too much attention to, or are meddling in, the management of the organization that is expected to carry out their policies. And if the policymakers start getting wrapped up in the problems being faced not only by top management, but by the organization's technicians, the reasons for concern can become acute. The policymakers are supposed to keep an eye on the big picture, not the little details. A University's Board of Trustees is expected to look after the welfare of the overall organization, not the day-to-day dealings between deans and departmental chairs, and certainly not the daily charting of progress in research labs. Similarly, on a large ship with a sizeable crew, the captain is expected to be at the helm, setting the course of the ship, not on the deck supervising the sailors, and certainly not down in the engine room with the mechanics.

In short, experience has taught us that, for a top-level policymaker in an organization, it is often more important to avoid "getting caught up in the details" than to know them reasonably well. For the people who serve on Boards of Trustees and Boards of Directors, a familiarity with detail is as likely to be harmful as helpful. A technical background can be useful, to be sure--particularly if it is kept "in the background"--but if the Trustees start to sound like technicians, it quickly raises the question of whether they are spending so much time focusing on the details that they are failing to keep sight of the larger picture. In short, the job of a Trustee is to act as a generalist, a person who looks after the whole instead of the parts. The organization is expected to hire specialists to look after those "parts," and the prudent Trustee both allows and expects the specialists to do their jobs.

With all of these acknowledgements aside, however, it is clear that there are still times when a prudent Trustee will begin to pay closer attention to the specialists--to question them, for example, or to wonder if the specialists are failing to carry out the jobs they are expected to do. Even here, however, the "warning signs" tend not to be highly technical, but rather to reflect a kind of broader "common sense."

In the brief discussions on this topic that I've managed to hold with high-level policymakers, they have tended to list four main types of factors that might cause them to question recommendations from their specialists. Suspicions are raised, for example, if it appears that the expert might have a vested interest in the outcome--witness, for example, how suspicious a dean will become if a department chair claims that his or her department needs more money than all of the others combined. Concerns are also raised if the expert's recommendations or activities have important implications for other parts of the organization, or if the expert fails to recognize the ways in which his or her specialized activities are constrained by the larger picture. To use the common phrase, the policymaker is likely to become concerned if it appears that the expert is failing to see the forest for the trees. A third reason for concern would be created if a given expert's past activities or recommendations had proved to be been wide of the mark, or had led to problems and difficulties. The fourth would be if other persons with expertise in the same field were to start warning the policymaker that something seemed to be seriously amiss. In this and in each of the other cases, however, the policymaker's gut-level trust of the people in question would be likely to play a key role in guiding the response to any such warning signs.

We might also think for a moment about what kinds of implications or problems would cause particular worries. In my own conversations with them, policymakers have tended to identify three main categories of implications as deserving particular scrutiny. In the first category are situations that have a large element of the unknown. Activities that are familiar and that draw on a large body of experience are not nearly as worrisome as activities that get the organization into areas where it has less of an experience base, or where the ratio of knowledge to judgment and guesswork is not as high. The second category includes be activities where the potential consequences of a mishap--specifically including an unexpected as well as an "average" or "more likely" mishap--might be especially severe. It's unwise to put all of the organization's eggs into any one basket, for example, even if it is a very good-looking basket. The third category of implications would include cases where potential problems, if experienced, would be difficult to correct, or at worst, essentially irreversible.

I'm sure that a more exhaustive search could develop a longer list, but these seven basic points--four ways in which an organization's specialists might come under closer scrutiny, and three types of situations that might have especially worrisome implications--should be sufficient for our purposes. While there is not likely to be anything on this list that will seem terribly new or insightful to an organizational specialist or management consultant, that is not the purpose. My purpose here, in fact, has been to come up with a standard, typical, textbook-type list. The point is in with what we do with the list.

Imagine now that you are on the Board of Directors for one of the largest and most complex organizations in the history of the world. Your organization is sufficiently large that you can afford to do some experimentation in research and development and even do a bit of experimental marketing. You also happen to be fond of new technologies, and thus you're inclined at least to give them a chance. Accordingly, when the folks down in Section X of the company suggested several years back that you give them a large budget to develop a totally new but promising technology, you agreed. Suppose further that they came back after an initial period of experimentation with highly enthusiastic reports, concluding that the new product could be produced quite safely and cheaply, providing a clean and economical alternative to some of the things your organization had done in the past. Since the folks in Section X were reputed to be some of the brightest and best in your whole organization, you congratulated them and gave them the money to go ahead. You might even have congratulated yourself, as well, on having shown the foresight to encourage their innovations.

Suppose, however, that things didn't work out quite according to plan. Suppose, for starters, that the implementation of the technology proved to be a bit more complex than you expected. Suppose further that the construction of the X-Plants cost significantly more than projected, with the X-folks coming back first to report a 10% cost overrun, then a 40% overrun, then overruns that finally wound up being in the range of 100, 200 or even 700%. By now, presumably, you would be starting to wonder just how much you should trust the projections from the X-folks in the future. Suppose further that it turned out that you were starting to hear murmurs of protest from other sectors of your organization--protests to the effect that the new X-product still had far more problems than Section X admitted, or that the X-folks didn't really know what they were doing in the first place. Some people in the Z-branch of the organization, while clearly expressing a minority view, might even suggest the potential ramifications of the X-problems could actually call into question the future viability of your organization itself. As a prudent policymaker, and one who felt a real sense of responsibility for your job, you wouldn't want to overreact to such reports--but neither would you want to dismiss them too lightly.

With all of these warning signs, in fact, it is highly likely that you would want to reexamine your own original commitment to project X. You might not want to kill it outright, particularly given the substantial investment you had already made, but you might start to reevaluate and to ask whether it might not be possible to take a more conservative, go-slow approach, or even to place a moratorium on all further development of the project until your questions had been satisfactorily addressed.

In case it is not already clear, everything I have said so far could be applied to the case of the nuclear power industry and to the group that, in a democracy, is in many ways the ultimate Board of Trustees--the general public. The public has extremely little knowledge of the technical details of the industry or the nuclear fuel cycle, just as members of a typical Board of Trustees or Directors would not be expected to have a detailed familiarity with the X-plant. What they do have, however, is a series of the very kinds of warning signals that would draw attention from a "real" Board of Directors.

The key proponents of the technology tend to be people who, while technically trained, do stand to benefit from implementation of the technology, if only in the form of future employment and research opportunities. That in itself might not be too much of a problem, in that it is a common arrangement, but there are other red flags. Some of the early efforts to promote the industry, ranging from public relations films to Atomic Energy Commission pamphlets, may have been a bit too enthusiastic in describing the benefits or downplaying the problems that, after all, would be expected with any new industry. Cost overruns have become a pervasive problem in the nuclear power plants that have been completed in recent years; the attention to management and waste control at some facilities has been less enthusiastic than it should have been; and particularly in the aftermath of Three Mile Island, the critics of the industry seem to the public to be a bit more credible today than they would have seemed a decade or two ago. At least some scientists are among the people who argue that nuclear technologies are unsafe or insufficiently understood. As Paul Slovic has demonstrated elsewhere in this volume, the events of the recent past have been sending "signals" that the technology is not as well understood as people might hope, and that the consequences of a potential accident, while perhaps unlikely, could be both severe and essentially irreversible. Indeed, the notion of "irreversible" takes on additional meaning when the public hears that the official planning horizon for a high-level nuclear waste repository is 10,000 years, a length of time essentially equivalent to the recorded history of human activity to date. The list of examples could easily be expanded, of course; the point is that the public's experience with the nuclear industry, and with nuclear wastes in particular, can easily be seen as providing examples of all seven kinds of the key warning signals noted earlier.

By now, many of you are presumably thinking about the counter-arguments. The cost overruns have resulted from a variety of factors, including some, such as interest rates and government regulations, that are essentially outside the control of the industry. The early promotional literature was intended to get people to think about the technology in terms of its peace-time potential, not in terms of mushroom-shaped clouds, and a certain downplaying of the problems or uncertainties might have seemed necessary at the time. We all underestimate the problems that might crop up in implementing an idea, whether it be in the form of writing a new paper or installing a new kitchen sink.

All of these objections are legitimate, but to a certain extent, they all miss the point. Put yourself again on the Board of the large organization that I described a few minutes back. In all likelihood, product X wouldn't have been the first or the last effort in the organization that didn't work out quite as planned, and presumably, a prudent decisionmaker wouldn't move to kill the whole effort the first time a problem popped up. You might not even bother paying attention to such details until it started to seem as though there might be a pattern of problems with the X-plant. Even then, you'd probably want to get a report from the X-people themselves as to their perceptions of the reasons for the problem and of the possibilities for doing better in the future.

But again, I ask you to think like a policymaker. If the people in project X seemed to be reasonably forthcoming about the problems, you'd probably have greater confidence than if they seemed to be defensive--whatever the technical content of their comments--since the defensiveness might be a sign that the people in section X would continue to "defend" their past efforts, even where those efforts had been misguided, rather than to try to correct the problems in the future. You'd also pay close attention to the major reasons being listed. If the people in project X reported that they'd run into some unexpected difficulties, or that their cost overruns had been caused by factors beyond their control, such as government regulations, you would probably be inclined to take them at their word, particularly if you still trusted them, at least for a while.

And yet eventually--and certainly after a period of a decade or more--a prudent Trustee or Director would consider doing what real Boards of Directors often do: terminating the experiment. You might conclude that the excuses sounded reasonable enough, and that the people on project X seemed to be basically competent and well-meaning individuals. Even so, you would also know that persons in other sections of the company somehow didn't need to resort to such excuses. You'd also know that, for whatever reason, project X wasn't living up to its potential--or at least to its advance billing. As a member of a real Board of Directors told me about a real project not too long ago, "sure, you want to give new ideas a chance, and as a decisionmaker, you don't want to get into the habit of getting involved in every little problem that comes along. But you also don't want to get into the business of ignoring the problems, or of going on 'promise' alone. Eventually, people have got to turn that 'promise' into 'performance.' If they don't, then ultimately it's time for the decisionmaker to make the decision--and sometimes, it's the decision to cut them off."

Conclusion

Overall, we may need to reexamine our willingness to decry the differences between "real" and "perceived" risks. Strictly speaking, it is scientifically inappropriate to refer to our current estimates as identifying the "real risks" of a repository, since we have not yet constructed a high-level nuclear waste repository, and we do not have the operating experience on which reliable estimates of the "real" risks could be based. Rather, in terms of the actual empirical evidence, it is more accurate to conclude that we have at least two sets of risk estimates--those that are believed in the scientific community and those that are believed in the public at large--at that the two diverge.

Perhaps the simplest way to summarize the foregoing discussion is to note that scientists and the general public tend to have dramatically different levels of faith in technology--and to realize that "faith" is in fact the correct word for describing the orientations of scientists as those of the general public. As responsible scientists are often among the first to point out, those of us in the scientific community are neither omniscient nor infallible. Even spending a lifetime in studying natural laws may not allow one to repeal any of those natural laws--and that may include Murphy's Law.

Anyone who has spent a significant amount of time in science knows that errors and missed guesses are common, not rare. Experiments fail to work properly, cherished hypotheses are demolished by the actual data, papers take three times as long to write as had been expected, and the phone always rings at the wrong time. While both the scientist and the member of the general public have some recognition of this fact, however, the two are likely to differ substantially in interpreting its implications. To the scientist, such errors and problems tend to be altogether unremarkable; the point is simply to learn from one's mistakes, and indeed, a popular book has recently examined "the role of failure in successful design" (8).

The common citizen, however, has learned for good reason to be suspicious when things fail to work as advertised. The world is full of con artists, stereotypical used car salesmen, and others who attempt to sell products that fail to live up to their advertised performance. Under the circumstances, it is not the least bit unreasonable for a citizen to ask what danger, if any, might be caused if a given promise fails to be fulfilled.

Whether we like it or not, the public clearly sees nuclear technology as having failed to live up to its advance billing. In addition, nuclear technology shares with a limited number of other scientific applications, such as toxics and biotechnology, at least a potential for mistakes that could be genuinely catastrophic. While these observations are undeniably frustrating to many scientists, the point that needs to be made is that public sensitivity to the potential for disasters may not be without its benefits. It is a common finding that persons in any occupation may have a tendency to underestimate the risks to which they expose themselves, and there is evidence to suggest that scientists may share a number of cognitive errors commonly found among the general public, including errors such as a high level of confidence in estimates that turn out to be incorrect (4). It may be, in short, that the views of the general public are not only different from those of scientists, but may actually be in certain and very limited ways, superior.

The limitations are important to keep in mind. The scientific community's estimates tend to be explicit and quantitative, as well as reasonably low, while the estimates among the general public tend to be qualitative and relatively vague, if at least implicitly high. The limitations, however, may not provide a sufficient basis to conclude that the public's views are either ill-informed or irrational. They are certainly not a sufficient

basis to conclude that the public reactions should be ignored instead of analyzed.

The actual socioeconomic impacts of a repository will depend in part on the public's perceptions and understandings of repository-related risks. While the public's assessments may differ from scientists' assessments, we need to acknowledge that scientists' assessments, too, are far from being infallible. And finally, while public assessments have often been attacked as "irrational," they may in fact contain a good deal more "common sense," or even prudence and wisdom, than is commonly acknowledged.

Having offered these observations, I also need to provide the accompanying caveats. The major caveat is that these comments are intended to be illustrative, not definitive, and that they can easily be carried too far. Many members of the public "Board of Trustees" are lazy, unwise, or so thoroughly influenced by their own vested interests that their thinking might not be affected even by clearly relevant information, although much the same could be said about people on "real" Boards of Trustees. Nor should anyone assume that I am arguing that ignorance of a technology is somehow the same thing as wisdom about it, or that anti-nuclear activists are somehow inherently wiser, more skillful or more "moral" than pro-nuclear activists. I am in no way claiming that members of the general public are always or even usually "wiser" than the members of the scientific community--only that it can happen, in some cases, and that we may thus need to realize that public views can have greater legitimacy than is often assumed. The scientific way to approach public perceptions, in short, is neither to damn nor to dismiss, but to seek to analyze and understand.

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