RADIOACTIVE WASTES AND THE SOCIAL AMPLIFICATION OF RISK

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ABSTRACT

A significant problem in radioactive waste facility siting is that apparent small risks or minor risks events produce substantial public concern and social impacts. The reasons for this difference in public health and societal impacts is not well understood. This paper explores the issues involved in the social amplification of risk, using the risk associated with site characterization as the example. Noteworthy as sources of amplification are the information flow associated with risks and risk events including the large volume of information, the extent of dispute, and misinformation and rumor. Such information passes through the mass media and interpersonal networks. The major mechanisms involved in risk amplifications are discussed and their likely impacts on society described.

Radioactive waste facility siting, it is increasingly clear, belongs to a special class of technological and public policy problems. Siting hazardous facilities, whether oil refineries, hazardous wastes, or nuclear power plants, has become one of the most difficult aspects of technology deployment. While the "backyards" problem has long been the bane of siting prisons, half-way houses, and town "dumps," radioactive waste facilities apparently introduce new dimensions of concern and difficulty. The configuration of the problem includes:

- a new and untried technological system
- substantial equity and value issues
- uncertain risks
- high levels of public concern and fear
- intense media attention
- differing expert and public assessments of risk
- struggles over control of decisions

Complicating this situation are the limitations in the existing fields of applied analysis in internalizing the scope of issues into existing analytic structures. No single field of inquiry is well equipped to engage such an intrinsically interdisciplinary set of questions. Social impact assessment has traditionally focussed upon the community impacts typically associated with the introduction of industrial facilities into small, rural communities. The approach has generally conceptualized the nature of impacts as strongly related to (1) the nature of the project or facility, (2) the number and characteristics of new in-migrants, and (3) the nature of the host community. While the field has recognized that risk-related impacts do not fit this traditional schema and have designated them as "special impacts" (suggesting that they fall outside existing analytic approaches), existing conceptual structures offer few insights into their epidemiology, sources, and management options. For its part, the field of risk assessment has generally emphasized public health and (perhaps) economic impacts of potential risk events associated with technologies or particular facilities. Although researchers have made important strides in relating such risks to public perceptions and response, the broader linkage to social impacts and potential management systems has generally yet to be conceptualized.

In this paper, we examine one of the more difficult problems involved with radioactive waste management, namely the tendency for apparently minor risks and risk events to generate high levels of public concern and associated social impacts seemingly out of proportion to their public health or environmental significance. Our intent is (1) to clarify the nature of this problem, and (2) to introduce an overall conceptualization, which we term the social amplification of risk, to suggest different processes which are at work.

RADIOACTIVE WASTE RISKS

The major risks associated with a high-level nuclear waste repository can be grouped into five major clusters:

(1) the risks of site characterization. The initial set of activities designed to characterize the site, while not posing the level of public health risk of subsequent stages, is also not risk-free. In particular, test drilling and underground studies pose some limited environmental risks, while operational and transportation accidents pose other risk possibilities. These, and the potential presence of limited amounts of

radioactive tracers or experimental materials, have potential for events which may affect public perceptions and generate broader social impacts.

(2) transportation risks. Transportation risks should receive careful analysis for a number of reasons. It is only recently that the planning of the nuclear waste transportation system and logistics has received detailed attention by the DOE. Since transportation may be either by rail or truck mode to a repository site and since these modes involve different transportation risks (with rail generally believed to pose the lower overall risk but a higher worst case event risk), the design of modal transport is significant. A number of issues have been raised about radioactive waste canisters, including quality assurance deficiencies, undue reliance upon cask integrity, inadequate regulatory inspection and implementation, inadequacies in state emergency response capabilities, and limitations in the design of tests for assessing cask performance. Furthermore, the data base concerning low probability/severe accidents events is limited (particularly for rail) so that uncertainties exist in estimating this set of risks of greatest concern. Finally, even if serious accidents with radioactive releases do not occur, incidents involving less serious accidents may nonetheless have serious and widespread repercussions on economy and public response.

(3) repository pre-closure risks. Accidents may be expected to occur in the above-ground activities at the repository during both construction and operation phases. Construction risks will tend to resemble those of other large industrial and mining operations, since radiological hazards will not be present. Particularly close attention should be given to preclosure accidents involving the potential for radioactive releases, with exposure possible to both workers and the public. A variety of accident scenarios has been identified and assurance is needed that the scenarios adequately bound the range of accidents which may occur. Potential radioactive releases also need to be related to local weather conditions to assess whether the projected off-site risks are sufficiently conservative.

(4) repository post-closure risks. The long-term risks posed for the repository depend heavily upon the adequacy of the engineered and geologic barriers. The risks involved include both the period of so-called fission product hazard, extending perhaps 500-700 years into the future, and the much longer term actinide-dominated hazard period. Since risks to both nearby and distant future generations are involved, important equity considerations are present which have relevance for both risk management designs and mitigation and compensation planning. Specific issues of long-term risk which must be addressed include:

- the potential for natural catastrophic events and their possible impacts upon a repository over very long periods of time
- the sufficiency of the scientific data base concerning heat and radiation impacts upon long-term repository performance
- the soundness of estimates of the risks associated with purposeful future human intrusion from resource exploration and ways to warn future generations if knowledge is lost

(5) retrieval risks. The potential always exists, in light of the 50-year retrievability requirement for the repository, that the wastes may need to be retrieved. Such a situation would necessarily pose risks, to the workers involved in retrieval, to nearby publics, and (perhaps) to the environment. These risks have received limited attention as yet but need to be carefully assessed.

THE RISKS OF SITE CHARACTERIZATION

Site characterization refers to the program of exploration and research, both in the laboratory and in the field, that will be undertaken to establish the geologic conditions and the ranges of the parameters of a particular candidate site, relevant to the procedures under 10 CFR Part 960. The borings, surface excavations, shaft excavation, and other in-situ testing at depth needed to determine the suitability of the site for repository will be done pursuant to a detailed site-characterization plan. The U.S. Department of Energy (DOE 1985) developed the specifications of what the plan must include.

The Yucca Mountain final Environmental Assessment (see DOE 1986a, 4-1 to 4-22) and the socioeconomic and environmental monitoring and mitigation plans for site characterization (DOE 1986b, 1986c) suggest a key set of activities and data summarizing site characterization at Yucca Mountain:

- two shafts (one 12 feet in diameter; the other 6 feet) to be drilled, with underground drifts
- 29 deep drill holes
- 244 shallow drill holes
- access roads to each drill pad
- 20 trenches
- off-road vehicle travel
- 20 acres cleared for surface facilities; 605-680 acres to have soils disturbed
- rock-storage pile to accommodate 1.3 million cubic feet of mined rock
- underground blasting
- potential release of naturally occurring radionuclides and resuspension of radioactive materials previously deposited during atmospheric testing at the Nevada Test Site
- use of radioactive tracers and shielded sources
- reclamation activities
- a peak workforce of 690 direct and indirect workers (40% direct)
- 60 additional worker vehicles between 5-6 p.m. daily and one truck shipment per day on U.S. 95
- time duration: 55 months

Characteristically, risks, such as those of site characterization, are identified, through analogous activity or fault tree analysis, by types of events which may reasonably be expected to occur, and by

estimation of the public health and environmental consequences likely to be associated with the events. Sometimes, depending upon the imagination of the analyst and the completeness of the assessment, highly unlikely events or combination of events may be included. Typically, the risks are stated in broad outline, usually with numerical estimates of selected expected consequences over the period of the activity or facility performance. Consider, for example, the U.S. Department of Energy's Assessment of the major impacts of site characterization risks at the Yucca Mountain site, which it estimates in its final Environmental Assessment (DOE 1986, 4-22 to 4-39) as involving:

- removal of wildlife habitat (705 acres of habitat will be disturbed). The consequences will be of particular note for the desert tortoise and Mojave fishhook cactus which may become additions to the List of Endangered and Threatened Species. A density of less than 20 tortoise burrows per square mile suggests potential disturbance of up to 20 burrows over the 705 acres of disturbed habitat.
- increased potential for range fires due to increased human activity and off-road driving
- minor particulate and gaseous air pollution
- 0.13 death and 14 worker injuries over 55 months due to excavation of exploratory shafts
- potential exposure to naturally occurring radionuclides and to resuspension of radioactive fallout from atmospheric testing of nuclear weapons
- potential worker exposure to radioactive tracers
- disturbance of cultural resources at four sites eligible for nomination to the National Register
- small to insignificant social and economic impacts

This risk assessment, we hasten to add, is quite characteristic of what prevails in environmental assessments, but still provides remarkably little insight into the scope of consequences which may occur and even less about the social significance of the risks of site characterization. This is because it neglects the broad interaction between risk and its social settings. Specifically it misses:

- the multidimensional (and especially qualitative) aspects of risk
- secondary (and some primary) consequences (e.g., stress, anxiety)
- interaction between public concern and risk events
- significant risk events (as opposed to consequences)
- the effects of sequences of events as opposed to single events
- feedback to risk from social sources
- social contributors and co-contributors to accidents
- the issues posed by differences in expert and public assessment of risk

THE SOCIAL AMPLIFICATION OF RISK

The need for completeness in risk assessment demands that analysis address how risk and risk events produce associated social impacts which either substantially exceed the apparent health or safety effect or which act to enlarge the risk itself. We term this process the social amplification of risk. In the discussion to follow, we identify ways by which apparently small risks or risk events may be amplified into larger social impacts and public concerns, using site characterization for a high-level radioactive waste repository as our example.

Sources

The roots of social amplification of risk lie in the experience of risk, particularly in direct personal experience and in more indirect, or secondary, experience through information received about the risk, risk events, and management systems. Direct experience with risky activities or events can be either reassuring, as with automobile driving, or alarming, as with tornadoes or floods. Generally, experience with dramatic accidents or risk events increases the memorability of the hazard, thereby likely heightening the perception of risk. But direct experience can also provide repeated feedback on the nature, extent, and manageability of the hazard, affording greater perspective and capability for avoiding risks. This is typically the case with occupational hazards, for example. While direct experience can serve as a risk amplifier, it undoubtedly also acts to restrain amplification. Understanding this interaction for different risks and different experiences is a continuing research need.

Where direct personal experience is lacking or minimal, individuals learn about risk from others. Information flow becomes a key ingredient in public perceptions and attitudes. Key attributes of information which influence the social amplification of risk are volume, the degree to which information is disputed, and the extent of exaggeration or misinformation.

Independent of the accuracy and particular content of information, large volume of information flow may serve as a risk amplifier. This occurs for several reasons. In an analysis of media coverage of Love Canal and Three Mile Island, Mazur (1984) argues that the massive quantity of media coverage not only reported the events but defined and shaped the issues. Repeated stories, of course, direct public attention to particular risk problems and away from competing sources of attention. Moreover, the media tend to become the battleground where various participants compete for advantage. However balanced the coverage, it is unclear that reassuring claims can effectively counter the effects of fear-arousing messages. *In* Alvin Weinberg's metaphor, it is much harder to "unscare" people than to scare them. The second reason lies in individual risk perception. High volumes of information mobilize latent fears about a particular risk and increase the recall of previous accidents or management failures or enlarge the extent to which particular failures, events, or consequences can be imagined. In this way, technologies or activities may come to be viewed as more dangerous.

The second attribute of information is the degree to which factual information or inferences are disputed by individuals or organizations regarded as credible by interested numbers of the public. Debates among

experts, it is now clear, tend to increase public uncertainty about what the facts are, increase doubts about whether the hazards are really understood, and may decrease the credibility of official spokespersons (Mazur 1981). If the risks are already feared by the public, then increased concern is the likely result.

Exaggerated or erroneous information is undoubtedly a powerful source of amplification. The report during the Three Mile Island accident that a hydrogen bubble inside the reactor could explode within the next two days, blow the head off the reactor, and release radioactive material into the atmosphere certainly increased public fears around the nuclear plant. Similarly the accounts in some newspapers, following the Chernobyl accident, of "Thousands Dead,!" increased the memorability of that accident and the perceived catastrophic potential of nuclear power. If erroneous information sources find ready access to the mass media without effective antidotes, then large social impacts, for even minor events, become entirely possible.

Channels

Information about risk and risk events flows through two major communications network--the mass media and more informal interpersonal linkages. The mass media as risk articulators have received the bulk of scientific attention for their obvious role in public opinion formation and community agenda setting. Since it is impossible for public to gain knowledge directly for most hazardous technologies, it is very dependent upon the portrayal of risk management that it sees daily in the mass media. Since the media tend to cover disproportionately rare or dramatic risks, or risk events, it is not surprising that people's estimates of the principal causes of death are related to the amount of media coverage they receive. Moreover, content studies of risk portrayal in the media reveal considerable misinformation and distortion (Combs and Slovic 1979; Freimuth, Greenberg, DeWitt and Romano 1984).

Informal network of communications involve the linkages that exist among friends, neighbors, and co-workers and within broader social groups more generally. While relatively little is known about such communication networks, it is undoubtedly the case that people do not consider risk issues in isolation. If they are matters of concern, individuals will usually discuss them with others in their social networks. Since these friends and co-workers will tend to be laypersons without particular expertise, the potential for the introduction of erroneous or exaggerated information is high. Also, if the risk event is dramatic or the risk feared, rumor may be a significant element in perception formation. Moreover, since one's social group may share a particular cultural bias, or view of the world, particular attitudes or interpretations may be reinforced and integrated into larger frames of analysis. It should be expected that such interpersonal networks may lead to divergent risk interpretations and levels of concern.

Mechanisms

Social amplification of risk occurs in different ways and at different levels. First information flow, particularly if in large volume or containing exaggeration or distortion, may heighten the individual's perception of risk. This will occur principally through the availability heuristic, making the risk more memorable or imaginable. If the risk has qualitative properties--catastrophic potential, newness, etc.--which increase public concern, then the amplification may be particularly large.

Second, the risk or risk event may enter into the agenda of social groups, or what Mazur (1981) terms the partisans, within the community or nation. This may occur either because a particular group has goals which include this risk issue or simply because political advantage is to be had by exploiting this particular risk or risk event. To the extent that risk becomes a central issue in a political campaign or conflict among social groups, it will be vigorously brought to public attention, usually coupled with an interpretation, indeed even ideology, of the risk management process. Polarization of interpretation and escalation of rhetoric by the partisan are not infrequent results. New recruits are drawn into the conflicts and socialized into the interrelation (Mazur 1981). These social alignments tend to become anchors for subsequent interpretation of risk management and may become quite firm in the face of conflicting information.

A third mechanism of amplification is that the occurrence of particular events, with associated information, provides clues (what some would term "signals") about the effectiveness of the management process. Relevant events may include those which suggest either that a new risk has appeared or that the risk is larger or different than previously understood. The Three Mile Island accident was an ominous event not because of the radiation actually released (which was small) but because it suggested that the technology was not sufficiently understood to be managed adequately. Slovic and colleagues have suggested (see Table 1) that accidents can be contrasted according to their high consequences on the one hand and their high information

TABLE I

Accident Scenarios Designed to Vary in Informativeness

Low Information Value	High Information Value
Bus skids on ice and runs off road (27 killed)	Nuclear reactor accident: Partial core meltdown releases radiation inside plant but not outside (1 killed)
Dam collapse (40 killed)	Botulism in well-known brand of food (2 killed)
Hundred-year flood (2700 killed)	New model auto steering fails (3 killed)
Meteorite hits stadium (4000 killed)	Recombinant DNA workers contract mysterious illness (10 killed)
Two jumbo jets collide on runway (600 killed)	Jet engine falls off on takeoff (300 killed)

Source: Slovic, Fischhoff, and Lichtenstein 1986.

(or message) value on the other. Risk events which tell society something it didn't know previously about a hazard may produce a much larger social reaction than events with much larger public health or safety consequences. Events which act as clues may include occurrences outside the risk "chain" (events, exposure, consequences) and in the risk management system, as suggested by Table 2. The role that clues play in public assessment of risk is not currently understood but may constitute another major route by which people from opinions about risks and technologies.

Stigmatization is another, albeit a poorly understood, mechanism of amplification. Stigma refer to the negative imagery associated with particular social groups or individuals. But areas or sites with high pollution, waste accumulation, or hazardous technology can come to be associated with such images. Wastes are a particular issue in such stigma since they tend to share a number of different negative attributes. Love Canal, the Valley of the Thousand Drums, and the Nevada Test Site all evoke vivid images of waste and pollution. Since the typical human response to stigmatized areas is avoidance, it is reasonable to assume that risk or waste-induced stigma may have significant social consequences. Particularly in areas where the imagery of place or area, such as the desert environment of Nevada or the lakes of Maine, is a major part of its economic base or quality of life, stigma formation may take on substantial social and economic importance. Unfortunately, little is known of the role of risk in creating stigma, the extent of aversion which results, and how durable such stigma prove to be.

A final mechanism of amplification is positive feedback to the risk itself due to social response to risk or risk event. If a transportation accident with radioactive wastes were to occur close to a repository site, for example, it is possible that protests and attempted blockage of the transportation route could occur. Such actions could themselves become initiating or co-initiating events in a future accident. Or an accident in waste-handling at the facility could lead opponents, or disgruntled workers, to replicate the event through sabotabe. Given the strong possible concerns over uncertain technologies or risk, a wide variety of mechanisms exist which may add to the risk potential at the various stages in the development of the hazard.

These different mechanisms of social amplification of risk can occur singly or in combination; indeed they may be interactive. It is likely that the outcomes in many cases will greatly exceed the apparent public health or environmental consequences.

CONCLUSIONS

On the basis of the discussion above, we conclude that

(1) the risks of site characterization will likely have more significant impacts than those indicated by traditional social impact analysis or risk analysis.

(2) Apparent minor risk or risk events can have large social, economic, and institution impacts through a process which we term the social amplification of risk.

(3) While the components and structure of social amplification are yet to be defined fully, it is apparent that characteristics of information flow, the messages which events carry, and the filters and amplifers which exist at both individual and social group levels are involved.

Our research group at CENTED (Clark University) is now developing a fuller and more formal statement which conceptualizes and provides examples of social amplification of risk.

TABLE II

Events With Potentially High Value As Clues

Events	Message
Resignation of regulators or corporate officials in "conscience"	The managers are concealing the risks: they cannot be trusted
Media report of off-site migration at a hazardous waste site	The risk managers are not in control
Scientific dispute over the validity of an epidemiological study	The experts don't understand the risks
Regulators state that the levels of containments in water supply involve only very low risks	The managers don't care about the people who will be harmed

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