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Risk Modeling in Agriculture: Retrospective and Prospective

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RISK PERCEPTION, COMMUNICATION, AND MANAGEMENT

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Introduction

In a comparison of the effects of two graphical devices — risk ladders and risk pies — on estimates of willingness to pay for hazardous waste minimization, Loomis and duVair (1993) show that risk communication is likely to have economic as well as social and behavioral impacts. In their study, more people vote in favor of waste minimization programs if exposed to the risk ladder, rather than to the risk pies. This study introduces a number of critical risk communication issues. First, the study illustrates that risk communication can have measurable effects on judgments about risk management strategies. Second, the study shows that communications can have unintended effects when normative interpretations of communications do not agree with their actual effects on perceptions. This raises the question of what goals risk communications have, and how best to reach such goals. Finally, by using risk ladders that include other risks to illustrate the effects of three risk reduction programs, the study places the perception of a single risk in a comparative context, which is qualitative as well as quantitative.

In the following, I will introduce each of these in turn, to provide you with some common ground for discussing risk communication. My own research indicates that it is a bad idea to do this without knowing something about what you know. My proxy for this information is the Loomis and duVair article, which some of you may have seen. So I will introduce each of these issues with the Loomis and duVair example. The paper ends with a brief discussion of public participation and a summary. Some of what is presented in the following is discussed in either Morgan, Fischhoff, Bostrom, Lave, and Atman (1992), or Fischhoff, Bostrom, and Quadrel (1993).

The Role of Risk Perception and Communication in Risk Management

It is easier to understand the why and how of risk communication if one keeps in mind how it fits into risk management. As stated above, the Loomis and duVair study (1993) illustrates that risk communication can have measurable effects on judgments about risk management strategies. Risk communication is thus often an essential component of risk management (Morgan et al. 1992).

Risk is the probability of adverse outcomes from hazardous processes. Hazards are "threats to people and the things they value" (Kates and Kasperson 1983). The hazard structure of pesticide use illustrates the possibilities for risk management intervention points (Figure 1).

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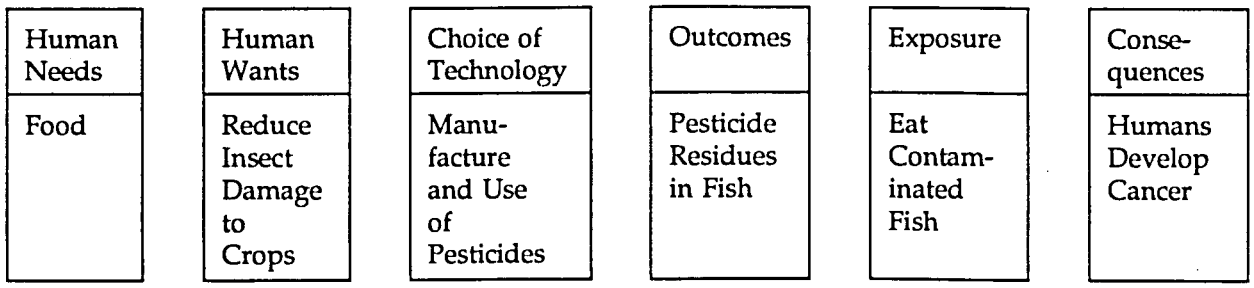

Figure 1. Human needs (such as food) lead to human wants (such as reducing insect damage to crops), which lead to choices of technology (such as the manufacture and use of pesticides), which lead to outcomes (such as pesticide residues in fish), which can lead to exposure (via eating contaminated fish), which leads to consequences (such as humans developing cancer). Every stage of this process provides a risk management potential (modifying wants, altering technology, blocking events, blocking outcomes, preventing exposure, and blocking consequences). Figure adapted from Hohenemser, Kasperson, and Kates (1985).

The basic problem of risk is that natural processes and human activities can lead to interactions of human and natural systems that create hazards. Risky processes consist of exposure, effects, perception and valuation processes, the outcomes of which can be identified as benefits or costs (Morgan 1993). Risk management entails modifying one or more of the parts of this process, including modifying human activities, modifying exposure or effects processes, modifying perceptions and valuations, or mitigating or compensating (to adjust costs and benefits). Some would also argue that modifying natural processes can be part of the risk management process, as in the case of seeding the ocean with iron filings (to reduce the risk of global warming).

Perceptions and valuations enter into all of these risk management intervention points, as well as into the latter part of the risky process itself. Thus risk communication can influence all of these parts of a risky process.

Rational Risk Perceptions

The risk reductions illustrated using the risk ladder and pies in the Loomis and DuVair study are equivalent, yet they influence readers differently. This shows that communications can have unintended effects, and that normative interpretations of communications do sometimes disagree with their actual effects on perceptions. There are a number of reasons for this, including how risk is defined by experts, how risk is defined and perceived by laypeople, and how judgment and decision making processes affect expert and lay judgments.

A formal definition of risk is: "quantitative measures of hazard consequences expressed as conditional probabilities of experiencing harm" (Hohenemser, Kates, and Slovic 1985). However, risk perceptions may not even agree with this general, formal definition of risk.

Tongue in cheek, Plough and Krimsiky (1987) depict lay concerns and priorities as "irrational": 'The "irrational individual" in risk assessment: In [health risk assessment], the individual does not make rational choices about risky behaviors such as smoking and not wearing a seat belt and therefore the individual takes irresponsible risks. In [environmental risk assessment] the faulty logic is reversed: The individual maintains an "exaggerated" fear of hazards which experts consider to be relatively safe.' Thus, in comparative risk assessment, health risk assessment and environmental risk assessment have the "irrational individual" in common.

Controversy can arrive from conflict between lay and expert comparative risk perceptions: In 1987, experts ranked indoor radon at the top of 31 environmental problems, along with worker exposure to chemicals in the U.S. EPA study "Unfinished Business" (U.S. EPA 1987). Roper polls of the lay public produced much lower rankings for radon — at or near the bottom of 25 environmental problems. Roper polls reveal that laypeople rank hazardous waste treatment and disposal facilities and abandoned hazardous waste sites (superfund sites) highest (Roper 1991).

The first of ten recommendations made by the Science Advisory Board to the U.S. EPA in its report "Reducing Risk" (US EPA/SAB September 1990) was that the "EPA should target its environmental protection efforts on the basis of opportunities for the greatest risk reduction." This recommendation has been interpreted to mean that, in fact, if radon is assessed as the greatest risk, with the greatest risk reduction potential, then EPA should target radon with its efforts. This would imply that radon should be prioritized over hazardous waste, and that the government should spend as much or more money on radon risk communication and management as it spends, for example, on Superfund sites. This interpretation, on the surface at least, implies a verdict that contradicts public opinion, which illustrates how the definition of risk, like that of any other key term in policy issues, is inherently controversial. The choice of a definition of risk can affect "the outcome of policy debates, the allocation of resources among safety measures, and the distribution of political power in society." p. 258, (Fischhoff 1989).

An expert might argue that risk is only the severity of the event and the uncertainty associated with that event. Lay definitions do tend to include both of these dimensions (Brun forthcoming). However, even if these were the only two dimensions included in lay perceptions, lay risk assessment might still differ from formal expert assessments, due to a number of heuristics and biases that influence such quantitative estimates.

While subjective estimates of relative frequencies are consistent across different response modes, estimates of absolute frequency are affected by the use of heuristics, such as *anchoring, compression,* and *availability* (Fischhoff et al. 1993). *Anchoring* is a tendency to focus or "anchor" on the first or most salient number one is given, and then to adjust inadequately from that when making other estimates. Anchoring shows a lack of feel for absolute frequency. *Compression,* which is underestimating the spread or variability in a range of estimates, can lead to overestimates of small frequencies and underestimates of large frequencies. *Availability* is the name given to the tendency to estimate the frequency of an event by the ease with which is it remembered. Thus, events that are easily remembered or imagined are available, and their frequencies overestimated. Also people tend to be *miscalibrated* or overconfident, showing inadequate sensitivity to the extent of their knowledge.

However, it is important to recognize that even formal definitions of risk do not always agree. A few formal definitions of risk (from Vlek and Keren 1991) illustrate the ways in which such definitions can differ:

- Seriousness of (maximum) possible undesired consequences.
- Probability weighted sum of all possible undesired consequences (average 'expected loss').
- Weighted combination of various parameters of the probability distribution of all possible consequences.

Thus, even experts disagree. In this context, it becomes fairly meaningless to claim that lay risk perceptions are *irrational.* What people perceive as an undesirable effect depends on their values and preferences. Should some formal definition be used, they may disagree with it because such numerical combinations of magnitude and probabilities tend to assume equal weight for both. However, there is much evidence that lay risk assessments depend on more than the severity of the event and the uncertainty associated with that event. Interactions between human activities and consequences are more complex and unique than average probabilities used in technical risk analyses are able to capture. In addition, institutional structures of managing and controlling risks are prone to organizational failure (Renn 1992).

It follows that a broader definition of risk is in order. Risk perceptions are "...people's beliefs, attitudes, judgments and feelings, as well as the wider social or cultural values and dispositions that people adopt, towards hazards and their benefits." (Pidgeon et al. 1992, p. 89). How risk is defined has environmental, political, social and economic consequences. One argument for using a broader definition of risk is the recognition that science has no special insights into what society should value (Fischhoff, Watson, and Hope 1984). Experts' quantitative risk assessments may be used in combination with information about social, political and ethical characteristics of the risk to make decisions about risk acceptability.

Laypeople can assess annual fatalities, but their judgements of "risk" correlate with other characteristics of hazards as well, including catastrophic potential and controllability. Psychometric research by Baruch Fischhoff, Paul Slovic, Sarah Lichtenstein, and others indicates that two or three dimensions of risk are important predictors of how acceptable people perceive a risk to be (e.g., Slovic, Fischhoff, and Lichtenstein 1980). The two primary factors are *familiarity,* which includes responses to questions about how voluntary, well-known, and controllable the risk is, and *dread,* which is assessed using questions about whether the risk poses a high catastrophic potential or a threat to future generations. The third dimension is a measure related to exposure, such as how many people are exposed. Risk is multidimensional.

Some researchers have divided perceived risk into two parts, hazard dimensions and outrage factors, the sum of which they claim equals perceived risk (B. J. Hance, C. Chess, and P. Sandman 1988; Hallman 1989; Wandersman and Hallman 1993). Hazard dimensions are the two dimensions discussed above in the context of formal expert risk assessments. Outrage factors include the kinds of attributes captured by variables such as familiarity in psychometric research. Hallman used this kind of model successfully to predict variability in perceptions of health risk (explained 53% of variability). As these researchers conclude, risk perceptions are supported by sets of consistent beliefs, not just irrational fears and unbridled emotions.

Risk Communication Goals

The above shows that a goal of "educating" risk communication recipients about expert risk assessments is overly simplistic and likely to lead to controversy and conflict.

Three kinds of goals can be adopted for risk communications: advocacy, education, and decision-making partnership (National Research Council 1989). An advocacy goal would be to enforce or encourage a behavior or belief. It can be argued that in so doing one is attempting to persuade the public to follow expert advice. In education, the goal is to inform the public. This subsumes a category of education that could be called decision support, in which the goal is to give the public enough information to enable them to make their own decisions effectively (according to their own values). The third kind of goal is to establish or foster a decision-making partnership. This requires that the public be involved actively in risk management and decision-making, including structuring the problem and selecting management options. The first two have been more commonly adopted than the third. They will be discussed here. Following a discussion of communication effectiveness, and how to design and evaluate risk communications to make them effective, a brief argument will be made for adopting public participation as a part of any risk management strategy. When used responsibly, public participation can be a mechanism for establishing decision-making partnerships that are critical to the success of many risk management problem-solving endeavors.

Advocacy

Often, risk communication has as its goal to encourage people to change their behavior, for example, to test for radon. A clear example of an explicit advocacy goal can be found in the revised Citizen's Guide (EPA 1992), in which it is stated that the risk communication aims to "encourage risk reduction." The guide includes this Surgeon General Health Advisory: "Indoor radon is a national health problem. Radon causes thousands of deaths each year. Millions of home have elevated radon levels. Homes should be tested for radon. When elevated levels are confirmed, the problem should be corrected."

Many risk communications advocate actions: Stop smoking. Wear your seat belt. Conserve Energy. Test for radon.

Persuasion. To many of the manufacturers or managers of technologies that create risks, "risk communication" means persuading the public that the risk from a technology is small and should be ignored. Sheila Jasanoff has suggested that: "risk communication is often a code [word] for brainwashing by experts or industry."

Public Education

A public education goal is simply to inform people about the risk. Unless this goal is further refined, the kind of information to be communicated can range from the technical to the arcane, and may not help the recipient make risk control decisions. For example, simply knowing that AIDS is a virus will not necessarily help one protect oneself from AIDS. Knowing that lead is one of the decay products of radon will not help a homeowner reduce radon concentrations in the home.

Public education has been targeted as an important goal for the U.S. EPA. From the ten recommendations in Reducing Risk: Setting Priorities and Strategies for Environmental Protection by the U.S. EPA Science Advisory Board (1990):

> "EPA should work to improve public understanding of environmental risks and train a professional work force to help reduce them. The improved environmental literacy of the general public, together with an expanded and better-trained technical work force, will be essential to the nation's success at reducing environmental risks in the future."

In contrast to the advocacy goal of the second edition of A Citizen's Guide to Radon, the first edition (EPA 1986) had a goal of public education, stated as: "This pamphlet is a joint effort by EPA and CC. Its purpose is to help readers to understand the radon problem and decide if they need to take action to reduce radon levels in their homes." This could even be interpreted as a goal of decision support.

Decision Support. A more specific education goal is to enable people to make informed decisions about risk. The kind of information that one disseminates in this context should be geared toward the risk control decisions that people face. For example: Radon is undetectable with the senses, but can be detected with a home test kit. AIDS can be transmitted when people share needles, because blood can be left in the needle. People are likely to face two kinds of decisions about most risks: decisions about their own and their family's exposures to risks, where they have considerable individual control, and; decisions in the processes of democratic government, where they have limited individual control, but can contribute to the political debate.

A mental models approach (described below) aims to provide decision support. While such communication may increase people's concern about a risk in the short term, in the long term, it is likely to be to benefit both individuals and society, as informed individuals are more likely to be able to act in accordance with their own best interests.

Communicating Effectively

Once an agency or organization has chosen or established risk communication goals, risk communication efforts should be evaluated in light of those goals. Although it may seem at first glance that the goals of education and advocacy conflict, there is some research that indicates that the most effective risk communications, in light of either goal, will share certain properties.

A common advocacy goal is to alter intentions or risk control behaviors. Risk communication is most effective in altering intentions or risk control behaviors if it conveys both threat, and efficacy. Threat, often discussed as "fear-arousal," is best conveyed if the communication evokes the severity of the risk along with involvement and personal relevance. However, a relatively recent review of research on the use of fear-arousal health promotion campaigns concludes that positive reinforcement may prove more effective than fear-arousal (Job 1988). In those cases where fear-arousal has been effective, specific risk-reduction behavior with short-term effects has been offered as part of the communication, and positive feedback on the effectiveness of that behavior has been offered to reinforce behavior and offset fear. Efficacy is

the feeling that one can control the risk effectively. (See, e.g., Job 1988; Witte 1992). Witte (1992) argues that the interaction of threat and efficacy determines the success of fear appeals.

For any goal involving decision support, it is important to recognize that regulators, scientists, and laypeople face different decisions about the same risks. A communication that informs one group usefully may not help another (Svenson and Fischhoff 1985). It is also important to recognize that risk control is a multi-stage process (e.g., Weinstein and Sandman 1992), involving stages such as becoming aware of the issue, deciding to act, acting, and maintaining risk control.

Mental Models

The risk ladders that Loomis and DuVair used include comparisons with other risks to illustrate the effects of three risk reduction programs. Any comparison or specific management strategy places the perception of a single risk in a context that is qualitative as well as quantitative. Conveying qualitatively what concrete measures can or will be taken to reduce a risk is key to imparting the sense of efficacy described above.

Communicators need to know where a recipient is coming from if they are to design messages that will not be dismissed, misinterpreted, or allowed to coexist with misconceptions. The mental models approach to risk communication is based on the fact that people interpret information based on what they already know (see, for example, Chi, Feltovich, and Glaser 1981; Otero and Kintsch 1993). Thus, to be effective, risk communication needs to take into account what people know. A mental models approach provides a way of discovering what people know and using it to develop risk communication.

We have developed a four-step approach to risk communication, based on people's mental models of risk processes (e.g., Bostrom et al. 1992):

1. Open-ended elicitation of people's beliefs about a hazard, allowing expression of both accurate and inaccurate concepts. This we call a "mental models" interview.
2. Structured questionnaires designed to determine the prevalence of these beliefs.
3. Development of communications based on both a decision analytic assessment of what people need to know in order to make informed decisions and a psychological assessment of their current beliefs.
4. Iterative testing of successive versions of those communications using open-ended, closed-form, and problem-solving instruments, administered before, during, and after the receipt of messages.

Mental models interviews, the development of a structured questionnaire, and risk communication design and evaluation are described below.

Mental Models Interviews. The first part of the interview is completely nondirective, in that it does not use preconceived response scales, and so lets the respondent structure the response. The interview opens with: "Tell me what you know about radon and any risks it poses." The interview becomes progressively more structured, but is still open-ended. Prompts follow for exposure processes, effects processes, risk assessment and management, risk comparisons, and personal risk. To illustrate, for radon exposure processes include the source,

concentration and movement in house, and uncertainty about exposure. Effects processes include the nature of effects and uncertainty about effects. Risk assessment and management includes the sources of the respondent's information about the risk, as well as all aspects of testing and reducing risk. Risk comparisons might be requested, for example, between radon and smoking. For personal risk, the respondent was asked "What about radon in your own home, is your own risk low or high?" The directive portion of the interview has varied in the studies done to date. For radon, a photograph sorting task was used (Bostrom et al. 1992).

The results of the interviews are coded into an expert decision model. The expert decision model used for radon was the representation of an influence diagram, which is a directed network showing the probabilistic dependencies between events in a process. For more details, see the summarized influence diagram in the paper by Morgan et al. (1992), or the more extended diagram in Bostrom et al. (1992).

Diagnostic Knowledge Test. A test is developed to administer to a larger group of respondents. The test is based on the results of the interviews and information from the "basic" level of the expert influence diagram, which is hierarchical. The interview process is so time and resource consuming that it would otherwise be exceedingly difficult to sample a large group of respondents. The test opens with an explanation of the response scale. For each statement listed the respondent is asked to circle the spot on the scale that reflects his or her opinion about that statement. The scale includes five possible responses: True, Maybe True, Don't Know, Maybe False, and False. An answer in the middle means that the proposition is in the respondent's opinion neither true nor false (i.e., to the best of her or his knowledge, the statement could equally well be true or false, or the respondent doesn't know).

The questions included cover both correct statements and propositions that people have made that can be regarded as misconceptions. The first five questions in the radon test were:

1. Under normal conditions radon is a gas.
2. Radon can be found outdoors.
3. Radon contaminated surfaces stay contaminated unless they are cleaned or renovated.
4. Over a few days, radon decays (transforms itself) into other substances.
5. Some radon to which people are exposed comes from rotting garbage.

Test results are analyzed to provide profiles of what sets of beliefs people have and how specifically they think about the risk, as well as what people on average do or don't know about the risk.

Designing Risk Communication. As stated above, prior knowledge and cognitive limitations, (e.g., heuristics, memory) affect how new information is processed. Risk communication design can be divided into two tasks: content design, and formatting. For a risk communication to be effective, both of these should take into account how people process information. The content of a risk communication should, as stated above, address recipients' mental models, and include the basic facts about how to identify the risk, and about exposure, effects and mitigation processes. These are taken from the expert decision model, which is designed to address the decisions faced by risk communication recipients. The format should highlight and summarize key information, and provide information in a usable format. That is, the format should be compatible with the structures of the decisions people face. Because risk

control decisions are made in several stages, communications should be targeted carefully so that the recipient finds the information appropriate for the decision stage he or she faces. Risk communication design is discussed more extensively by Atman et al. (forthcoming).

Empirical results from risk perception, communication, and decision making studies can improve communications in several other ways as well. For example, most risk communications include some statement of probability based on some exposure or dose. In this context, it can be tempting to use a verbal probability alone to simplify the presentation for the reader. However, the communicator should beware. Studies show strongly that the interpretation of verbal probabilities depends on the context. "Likely" in "likely to get AIDS" is unlikely to be interpreted the same as "likely" in "likely to catch a cold" (e.g., Wallsten et al. 1986).

Specific information about or frequencies of exposure may be understood differently depending on whether exposure estimates are represented cumulatively or for single exposures. There is evidence that people do not cumulate estimates of single exposures at a high enough rate (Fischhoff et al. 1993; Linville et al. 1993). Thus, it might be wise to communicate cumulative risk, depending on the circumstances.

Many risk communications include comparisons. In making comparisons, the communicator should bear in mind that risk is multidimensional. Which dimensions are being compared? A simple comparison of probabilities may imply a comparison on other dimensions, such as voluntariness, in which case the reader may find the comparison unacceptable or uninformative. The Chemical Manufacturers Association commissioned three of the best risk communication experts, Vince Covello, Peter Sandman, and Paul Slovic, to prepare a handbook for chemical plant managers on how to make risk comparisons. Based on a careful reading of the literature, these experts focused on the pitfalls of comparing risks. The handbook concludes with 14 paragraph-length illustrations of risk comparisons described with labels ranging from "very acceptable" to "very unacceptable." Roth et al. (1990) asked four diverse groups of subjects to judge these paragraphs on seven scales intended to capture the manual's notion of acceptability. Using a variety of analytical strategies, they found no correlation between the acceptability judgments predicted by the manual and those produced by the experimental subjects. Thus, even experienced professionals have limited predictive insight about risk communication. There is no substitute for an iterative empirical approach.

Given the state of the science of risk assessment, it is important to convey the uncertainties that exist in estimates of risk, although this is difficult to do. There are different kinds and sources of uncertainty, such as a lack of scientific agreement on interpretation of data, or a lack of data. There are also different techniques for conveying uncertainty, including graphs, verbal presentations, and the presentation of alternative estimates. Good risk communication simplifies and summarizes, but this must be done cautiously. Include where to go for more information, or glossaries and appendices with more information.

Evaluating Risk Communication. A clear set of objectives is needed for any evaluation. In the following, the assumed goal is to help people make decisions about risk. If the goal was to influence behavior, the evaluation should include some measure of behavioral change — preferably not a self-reported measure.

Communication evaluation methods can be divided into two categories: those that are based on the message, such as content analysis, or an analysis of communication structure based on examining the communication, and those that are based on how the communication is received (Schriver 1989). The latter are called audience-based evaluation methods. Audience-based evaluation methods can vary by structure and timing of data collection. Data collection can be open-ended or closed-ended, and can occur either while the communication is being read or heard (concurrently), or afterwards (retrospectively), based on what people remember after communication. In open-ended evaluations, respondents formulate their own responses. In closed-ended evaluations, respondents select between investigator-generated responses.

Using Mental Models Results. Table 1 shows an example of some of the results of an open-ended mental models interview, in which participants were asked to talk about indoor radon. Responses were coded into the influence diagram, when they corresponded to the statements in the diagram, or into a separate list of non-expert propositions. The table is adapted from Bostrom, Fischhoff and Morgan (1992).

	Percent of interviewees	Effects Concepts
Radon...	63%	causes cancer
	58%	affects plants
	38%	contaminates blood
	29%	causes breast cancer
	25%	contaminates (generally)
	21%	comes from garbage
	21%	contaminates water
	21%	*causes lung cancer*
	21%	*effects depend on smoking*

Table 1. Some effects concepts found in an open-ended mental models interview study. Adapted from Bostrom, Fischhoff, and Morgan (1992). Italicized statements are both correct and appropriately specific for decision-making about radon.

The results in Table 1 can be compared with the results of a recent national survey on radon (CRCPD 1993). In response to the question "Have you heard of radon?" Sixty one percent of the population of the State of Georgia claimed that they have heard of radon (N=601). By race, 69% of whites have heard of radon, while only 40% of those of other races have heard of radon. By income, 43% of those with a self-reported household income under $25,000 have heard of radon, compared to 67% of those with higher incomes. Clearly, risk awareness varies by socioeconomic status and by culture. Thus, it may also be appropriate, and in some cases necessary, to tailor risk communications for specific cultures or subpopulations.

Several empirical arguments can be made in support of a mental models approach to risk communication design and evaluation (Morgan et al. 1992; Atman et al. forthcoming; Bostrom et al. forthcoming).

1. In open-ended mental models interviews, half of the subjects omitted mitigation techniques, despite direct prompting, a fifth didn't mention any mitigation strategies in either the interview or a subsequent photo identification session, although most people expressed some exposure knowledge. This provides evidence that communicators should put risk information into a decision-making framework, to communicate what can be done, as in a mental models approach.
2. Omission of decay knowledge appeared to be correlated with contamination beliefs in over 30% of the subjects we studied. This kind of omission can be corrected if the communicator addresses exposure and effects processes completely at a basic level.
3. Participants in our studies exhibited knowledge that was less accurate than it was complete. In other words, some of the beliefs they stated were either very general, peripheral (not central) to the risk control decisions might face, or were simply erroneous. Knowledge should be specific enough to enable the communication recipient to effectively distinguish the risk from other risks, evaluate the risk comparatively, or make decisions effective risk control decisions. It follows that communicators need to address common misconceptions and put peripheral ideas into perspective.

It might seem tempting to simply ask a risk communication expert what to say. However, empirical evidence illustrates that this strategy is likely to fail. Because each risk is somewhat different, and any given communication expert is unlikely to have had experience with the specific risk in question, there will be new things to learn about the effects of communication about that risk. As shown in Roth et al. (1990) experimental studies show that the "best conventional wisdom" about risk communication can be off base. There are no risk communication experts who can reliably get the message design right without careful testing.

Public Participation

But education alone cannot resolve controversy. Arguing that the government must accommodate the will of the people, [Ruckelshaus] quoted Thomas Jefferson's famous dictum to the effect that "if we think [the people] not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion" (Ruckelshaus 1983, p. 1028). A year later, Ruckelshaus was not so cavalier on the same topic: "easy for him to say. As we have seen, informing discretion about risk has itself a high risk of failure." Ruckelshaus 1984, p. 160 (comparison taken from Slovic 1991).

A few all-too-familiar acronyms illustrate the power of public participation when conflict rules. The general stance of the public to any nuclear facility — as opposed to more supportive view of technical community is "NIMBY" — Not In My Backyard. Some kinds of facilities are likely to inspire opposition in virtually all of the local contexts where they are proposed, are can be called "LULU" — Locally Unwanted Land Uses. The more extreme general attitude rising from this kind of opposition is "BANANA" — ban anything near anyone's neighborhood anywhere. (Freudenberg and Pastor 1992).

It is essential, if one wants to reach decisions or acceptable solutions in these kinds of situations, to empower those at risk and try to establish shared values between involved parties. Without early and continuing involvement, public participation programs are likely to fail (Freudenberg and Pastor 1992). Risk communication used for persuasion is likely to impose

goals and objectives on the public, and thus preclude real interaction. Risk communicators need to inform the public and consult with the public to solve hazard problems.

What Matters?

In sum, risk communicators who define their task narrowly are setting themselves up for failure. The National Research Council provides a very broad definition: Risk communication is "...an interactive process of exchange of information and opinion among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management." (National Research Council 1989, p. 211). Good risk communication takes into account the research results this paper has presented, which are summarized here:

- People use what they know to interpret new information: their "mental models" of risks and prior beliefs about the risk communication source are likely to affect how they interpret risk communication (e.g., Morgan et al. 1992; Fischhoff et al. 1993).

- Both experts and laypeople use heuristics ("rules of thumb"). The use of heuristics can lead to biases. For example, cumulative probabilities may make an event seem riskier than the equivalent 'one shot' probability; whether a problem is framed in terms of gains or losses can affect judgments and decisions.

- People make decisions at each stage of risk reduction. So, in the case of radon, separate decisions can be made regarding testing for radon, retesting, mitigating, and testing again to see if mitigation measures are effectively reducing radon concentrations.

- People do not all face the same decisions. Individual circumstances differ; social and cultural contexts differ. For example, some individual differences in perceptions can be predicted by gender, knowledge, and education (e.g., Barke and Jenkins-Smith 1993). People also care about processes as well as outcomes. For example, people may view imposed risks differently from voluntary risks.

Keeping these points in mind should facilitate better risk communication, and lead to a better understanding of each others' risk perceptions.

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