J. ENVIRONMENTAL SYSTEMS, Vol. 22(2) 163-187, 1992-93

PUBLIC PERCEPTION OF WATER QUALITY RISKS—INFLUENCING FACTORS AND ENHANCEMENT OPPORTUNITIES*

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ABSTRACT

Public perceptions of the human health risks associated with water quality deterioration have been increasing in recent years, and a better understanding of the determinants of such perceptions and the communication of these perceptions to the policy community will facilitate water quality management. The objective of this study was to conduct a state-of-the-art literature review on factors affecting public perception of risk and levels of acceptable risk in relation to water quality, and to delineate research opportunities for such perceptions in relation to their usage in water quality management. Extensive literature searches yielded approximately 150 papers or other published items related to water quality risk concerns.

Although there have been few comprehensive studies of factors that influence water quality risk perception and the delineation of acceptable risk, many individual and combinations of factors have been identified as affecting perceptions held by different publics. Examples of such factors include whether or not pollution is visible, personal usage of the water resource, historical changes from emphases on bacteriological quality to the occurrence of toxic chemicals, education level, age, proximity to the problem, familiarity with the contaminant and source, trust in local public officials, involvement in decision processes, and poor risk communication efforts. Outrage factors such as whether the risk is voluntary or involuntary, familiar or unfamiliar,

*This article is based on the results of a research project at the University of Oklahoma sponsored by the National Geographic Society (Grant 4783 W-92). The authors gratefully acknowledge the support of the National Geographic Society. This study was conducted by an interdisciplinary team at the University of Oklahoma.

doi: 10.2190/93D9-JF0N-EEF8-W4PW
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controlled by self or controlled by others, memorable or not memorable, dreaded or not dreaded, or natural or unnatural, can also influence risk perception. Complications associated with identifying influencing factors include the facts that: 1) the water environment is technically and scientifically complicated due to hydrodynamic considerations, chemical processes, and the kinetics of bacteriological decomposition; 2) there are many uncertainties associated with risk identification and evaluation; 3) effective communication of risk information to different publics is difficult; and 4) conflicts may arise due to different perceptions of water risk between policy makers, scientific experts, public interest groups, the media, and individuals within the general public.

A fundamental research need in relation to water quality and risk perception is for a basic conceptual model which can be utilized and tested in terms of the factors which influence perceptions of water quality risks held by different publics. The conceptual model should incorporate both individual perception of risks as well as group perception of risks. Acceptable risk needs to be systematically defined and various causative factors or issues should be delineated. Very little information exists on how public perceptions of water quality risks are actually used by policy makers in planning and implementing water quality management programs. Research is also needed on institutional and interdisciplinary barriers to the development and transmission of information needed by policy makers and the general public in their formation of risk perceptions. Consideration should also be given to the degree that narrow disciplinary perspectives influence scientific and technical information communicated to policy makers and the general public.

INTRODUCTION

Water quality concerns encompass a number of specific considerations, including pollution or contamination issues associated with different media such as surface water, ground water, and/or coastal water; and the associated consequences of this pollution or contamination in terms of subsequent water usage and deterioration of resource features, recreational usage, and productivity. Examples of the implications of water quality deterioration include associated fish kills, reductions in opportunities for water usage for domestic or recreational purposes, and excessive aquatic plant growth. Due to necessary water quality requirements for specific uses, and the wide variation of such quality requirements depending upon the usage, water quality deterioration can also lead to increased water treatment costs prior to its usage. Other water quality related examples include lake eutrophication and salt water intrusion in coastal ground water [1].

Traditional surface water quality problems have focused upon the discharge of untreated domestic sewage into streams, rivers, and lakes; with attention for several decades also being directed toward the discharge of toxic organic contaminants and metals from industrial plants. Thermal discharge from power and/or industrial plants has caused concomitant reductions in the dissolved oxygen of receiving waters. Of recent emphasis have been nonpoint sources of water pollution as represented by both agricultural and urban runoff waters. Agricultural nonpoint sources of pollution are of concern due to their potential introduction of nutrients from fertilizers and/or pesticides into surface and/or ground water resources. Additional ground water pollution sources include [2]: septic tank systems, land disposal of municipal or industrial sludge, hazardous and non-hazardous industrial waste disposal via landfilling, municipal solid waste disposal via landfilling, leaking underground storage tanks, open dumps, surface impoundments, accidental spills, mining operations, injection wells, highway salt and other deicing chemicals, and various activities associated with resource extraction related to the oil and gas industry.

Water quality concerns and pollution issues also have been identified along the coastlines of the United States, with many of the sources of pollution representing those that are common for both surface water and ground water resources. Of particular importance in coastal areas is that these locations, which include estuaries, often represent highly productive zones in terms of fish, shellfish, and other organisms consumed by humans for food purposes.

Public perceptions of the human health risks associated with water quality deterioration due to pollution sources and resource exploitation have been increasing in recent years. These perceptions have influenced governmental regulatory program development and pollution control and remediation efforts. In fact, any strategy aimed at the effective management of the nation's water resources must include the inputs and perspectives of various publics. Consideration of perception of risks, levels of acceptable risk, and their balance with quality of life choices in the context of water quality issues is critical to the success of policy development and implementation. Obviously, societal decisions will have to be made to balance acceptable levels of risk with expenditures for pollution prevention and control, water supply development and protection, and remediation.

A better understanding of the determinants of risk perception and the communication of these perceptions to the policy community will facilitate more effective water quality management. Accordingly, the objective of the study summarized herein was to conduct a state-of-the-art literature review concerning what is known about factors affecting public perception of risk and levels of acceptable risk in relation to water quality and control of point and nonpoint sources of pollution. This study was sponsored by the National Geographic Society, with the complete results in [3].

DESCRIPTION OF STUDY

The literature included in this review was identified primarily through systematic searches of online databases and library systems. Using very general keywords (e.g., risk, public perception, public opinion, and risk communication in conjunction with water), initial searches were conducted of the extensive holdings of the Science and Public Policy Program (11,500 items) and Environmental and Ground Water Institute (6,000 items) libraries at the University of Oklahoma. Extensive searches were conducted of computerized online databases available through the DIALOG bibliographic retrieval system, including: Enviroline, Environmental Bibliography, Geobase, NTIS, Pollution Abstracts, PsycINFO, Social Scisearch, Washington Post Online, Water Resources Abstracts, and Waternet. Journals, such as Risk Abstracts, and various newsletters which are not included in the online bibliographic databases were reviewed physically for relevant literature. Searches also were conducted of several online library systems. In addition to the Library of Congress, the University of Oklahoma, Oklahoma State University, Massachusetts Institute of Technology, and U.S. Environmental Protection Agency libraries were searched. Generally, the searches were limited to literature published since 1980; however, this was not a rigidly observed guideline with respect to acquisition and review. Important or seminal works prior to that data also were included. The above process resulted in the acquisition of about 540 items, with about 350 considered relevant to the overall study, and 150 of the 350 items related to water quality concerns and risks associated with contamination.

This article highlights the key findings from the water quality-related references in terms of factors which affect risk perception in relation to water quality, and opportunities for enhancing public risk perception in relation to water quality concerns via research. These two themes will be addressed following a description of a conceptual framework for public risk perception in relation to water quality policy development and management.

CONCEPTUAL FRAMEWORK FOR RISK PERCEPTION AND WATER QUALITY CONSIDERATIONS

The formation, communication, and use of public perceptions of risk is a complex process involving numerous components and linkages. Figure 1 illustrates the relationships between the physical conditions and events that can engender water quality risks, scientific and technical information (STI) about risks from the expert community (scientists, engineers, hydrogeologists, economists, etc.), information communication, publics (individuals in the general public, interest groups, and associations) and the policy making community (elected and appointed officials charged with developing and implementing water quality policy), and the water quality policy process [3]. STI includes data that describe physical conditions and events, estimates of risk (e.g., death, injury, and illness) related to physical conditions and events (e.g., concentrations of chemicals in drinking water), and assessments of these risks and their seriousness. This information is communicated to both policy makers and publics via scholarly publications and conferences, mass media, interest groups, and government agencies. Information concerning dramatic physical conditions and events, such as chemical spills, often is communicated directly to policy makers and publics by the mass media without interpretation or evaluation by the expert community.

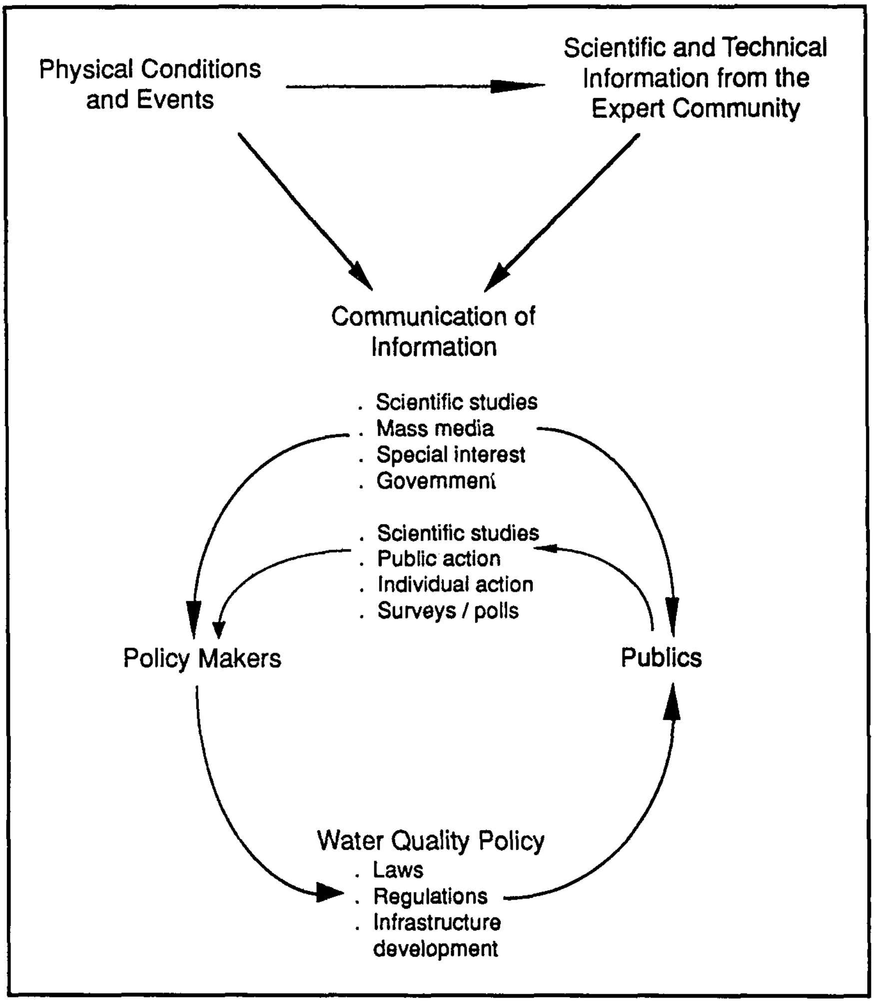

Figure 1. Risk perception in the water quality policy context [3].

Publics use STI, the opinions of their peers, and their own experiences to form perceptions of risk and to determine acceptable levels of risk. Policy makers receive information concerning public perception of risk through actions and communications of individuals and interest groups and from surveys, polls, and scientific studies that measure these perceptions. Among other factors, policy makers rely on their own perceptions of risk, the perceptions of their peers, STI from the expert community, and mass media information when developing and implementing water quality policy decisions. Policy decisions and actions can, in turn, affect public perception of risk related to the object of those decisions.

The model depicted in Figure 1 can be applied in any policy arena involving the mangement of risks both publicly perceived and scientifically assessed. The importance of such a model is derived from the need of society to ensure that risks are acceptable, both as measured scientifically and as perceived by untrained publics. Policies that manage risks must be technically feasible, economically realistic, and socially desirable. Implemented policies can have significant impacts on monetary expenditure and social welfare, measured both physically and cognitively.

In some instances proper management may entail policies which result in a reduction of the scientifically assessed risk. Examples in the water quality arena include regulation of industrial wastewater discharges and federal funding for municipal wastewater treatment plants. In other instances policies may entail modifying risk communication procedures to attempt to assuage public fears concerning a particular risk, or, alternatively, to increase awareness of risks. Policy makers are rightly influenced by both scientific assessments and public perceptions of risk, taking into account the strengths and weaknesses of each. Scientific assessments are only as good as the theories, equipment, and procedures that are used. While much effort has been devoted to ensuring that the risk assessment process is as "scientific" as possible, there are numerous decision points along the way that are influenced by social, cultural, ethical/moral, political, and economic values. When combined with lack of complete knowledge in many areas, e.g., human exposure assessment, the resulting risk assessment is fraught with uncertainty. Leaving the issues of accuracy to scientific debate, each member of society decides on an individual basis what level of risk is acceptable. These separate evaluations eventually merge to form the "public perception" of risk, and thus must be included in policy decisions. However, these perceptions are subject to many influences, and are open to many interpretations. When policy makers decide that public perceptions concerning a particular risk are incorrect or unfortunate, they are left with three choices: to respond directly to the perception; to attempt to change it with appropriate communication; or to ignore it.

Water quality policy is a particularly important issue in the modern world. Water, of high quality, is a human necessity. Threats to water quality come from many sources, such as industrial wastewater, municipal wastewater, non-point source runoff from agricultural operations and urban environments, and salt water intrusion. At the same time, little research has been conducted to investigate how people perceive water quality risks. A model which describes interactions between water quality risks, STI, information communication, the various publics, policy makers, and policy in the water quality arena would be highly useful in meeting future policy challenges in an economically and socially realistic fashion. This article represents one step in that direction.

It is important to note that many other factors which influence the various components and linkages are not depicted in Figure 1. For example, the quality of STI from the expert community is determined, in part, by the capabilities of available risk measurement and assessment techniques. However, the primary emphasis of this state-of-the-art review was on the formation of risk perceptions in various publics and the policy making community and the use of these perceptions in the processes of water quality policy development and implementation. Although the development and communication of STI are critical to the formation and use of risk perceptions and are important components of the water quality policy context, they were not a major focus of this review.

FACTORS AFFECTING RISK PERCEPTION RELATED TO WATER QUALITY

Many factors affect the perception of water quality risks as held by different publics such as water quality experts, elected officials, individuals in the general public, and public interest groups. This section is organized into surveys of pollution problems and general information related to time and other selected factors that seem to influence perceptions of environmental risk and problems. This is followed by information on "outrage factors" which are generic factors that have been determined to influence an individual's perception of risk, irrespective of whether the risk is associated with water quality concerns. The next subsection highlights an interesting study which identified factors which minimized the perception of water quality risk in a particular case study. This is followed by information on one-or-two factor studies which focus attention on particular influencing factors such as education. This is a lead-in to a subsection on the relationships between education, uncertainty, and risk communication techniques in terms of their influence on public perception of water quality risks. Finally, this section is concluded with some summary remarks related to the overall findings.

Pollution Surveys

A number of surveys have been conducted on public opinions related to water and/or environmental pollution problems. In some instances, water pollution concerns are evaluated in the context of other environmental pollution problems and societal issues. Some key factors which influence pollution survey results are whether or not the evidence of pollution is visible and whether or not information related to pollution problems and their associated risks is available to the public. Specific examples of pollution surveys, arranged in chronological order, include a 1969 survey of water quality problems conducted in Wisconsin by David [4]; a report by Kooyoojian and Clesceri [5] which suggested that lake water quality perceptions are related to personal lake use; a paper by Battisti [6] which argued that there is a distinction between socially visible and invisible pollution which can affect the reactions of citizens to polluting agents; and a 1987 mail survey of residents in three northern California communities which was used to assess public perceptions of technological risks, including contaminated drinking water, storage of toxic chemicals, and nuclear power plant accidents by Pilisuk, Parks, and Hawkes [7].

Changes in Water Quality Related Risk Concerns Over Time

Emphases on water quality problems and associated risk concerns have changed over time. For example, one study denoted the changes in risk considerations in addressing water quality/pollution problems in the twentieth century by comparing three historical issues; one involved protecting drinking water supplies from pollution in the 1900s to 1920s where the primary concern was associated with bacteriological contamination; one addressed industrial wastewater and public health concerns in the 1940s to 1960s wherein the concerns were associated with potential releases of organic chemicals and metals; and the third related to land disposal of hazardous waste and associated ground water contamination (e.g., Love Canal) which characterized the 1970s and 1980s [8]. Some lessons learned as a result of the comparisons made in these three case studies were:

- Disciplinary perspectives and conflicts affected public policy choices and outcomes. Different types of professional training involve alternative value systems and these values result in different estimates of risk.
- Indicators are important as a basis for the estimation of risk and the formation of public policy. The existence of the indicators themselves reflected a problem definition that defined the scope of the attack on the problem.
- Government was a participant in all three cases, but only in the last case, that of Love Canal, was the public an important actor. In the first two cases, the decision-making process was dominated by experts and policy makers; however, in the third case the public, believing itself exposed to unacceptable risk, became an important participant.

As a further illustration of changing perspectives relative to water quality risk over time, the issues related to concerns associated with waterborne disease agents, and which are the appropriate risk indicators, can be noted. For example, microbiologists have recognized the growing risk of potential waterborne pathogens such as *Campylobacter, Aeromonas*, and *Cryptosporidium*, and enteroviruses. The public may be concerned about exposures to any disease-causing organisms. According to Rose [9] the common waterborne diseases such as cholera and typhoid have been controlled in the United States since 1970; however, between 1970 and 1985, 502 waterborne disease outbreaks occurred. Over half (52%) were attributed to *Giardia*, while 38 percent were of unknown etiology. *Giardia*, a protozoan which causes diarrhea, is now the most frequently identified cause of waterborne disease in the United States, increasing from two outbreaks from 1965 to 1969, to fifty-six from 1980 to 1984 (Rose, Haas, and

Regli [10]). *Cryptosporidium*, a protozoan which causes a cholera-like disease, was recognized as a hazard in 1985. Both of these protozoans encyst and are resistant to chlorination. Most *Giardia* outbreaks can be traced to unfiltered water systems; most *Cryptosporidium* outbreaks are related to surface water contamination which penetrated treatment barriers.

Enteric viruses have also been recognized as an increasing risk source for waterborne disease, with over 100 types of these viruses identified. These enteroviruses, first isolated from sewage, include polioviruses, and echoviruses (responsible for meningitis, respiratory illness, and diarrhea), adenoviruses (which may cause eye infections and respiratory illness), and rotavirus (infant diarrhea). The enteroviruses can be recovered from treated drinking water, and may also contaminate ground water. Other microorganisms of concern in waterborne illness are *Legionella pneumophila* and heterotrophic plate count bacteria (HPC) including *Aeromonas*. The HPC have been used as an indicator of water treatment and quality, and are associated with opportunistic infections, as well as biofilm development in the distribution system. Biofilms, which can protect bacteria from disinfectants in the water, also provide nutrients for other bacteria and are associated with metal corrosion [9].

Within the last two decades there has been increasing attention to the reclamation and reuse of water which has been previously used and polluted. While the practice of water reuse has long existed in the United States, the key difference represents the fact that the reused water may now be utilized near the point where treatment is provided. For example, for many years individuals living near the mouth of the Mississippi River and using Mississippi River water as their source of water supply have been subjected to water which has been used multiple times throughout the central portion of the United States; in contrast, wastewater reclamation and reuse may now occur in the immediate geographical area where the wastewater is generated and treated. There are a number of specific issues that relate to public perception of risk that are associated with wastewater reclamation and reuse. For example, Cooper, while recognizing the risks of trace organics and microorganisms, has stated that with proper attention to water quality standards and reclamation plant reliability, high-quality water which should not pose a risk to consumers can be produced [11]. Cooper has also stated that there is a "dichotomy of thinking about drinking water standards on the part of many health professionals." The double standard arises from the belief that if water comes from a natural source, surface or ground, and meets accepted treatment, biological, and chemical criteria, it can be used by the community. In contrast, if the water meets the same criteria but is reclaimed water, without intervening "natural" exposure, then that water is unacceptable.

Both Arizona and Florida have mandated wastewater reuse in order to protect ground water and provide for long-term water preservation. Such reuse presents the risk of over 100 possible types of enteric viruses found in sewage, as well as bacteria and the protozoa *Giardia* and *Cryptosporidium*, all of which are important causes of waterborne disease. As it is "well known that biological indicators are inadequate for the assessment of virus and protozoan presence," Arizona has established standards for enteric virus and *Giardia*, while Florida has implemented specified treatment control based on type of reuse and potential for public exposure. Five states—Arizona, California, Colorado, Florida, and Texas—are considering the potential of renovating wastewater for potable use. Rose and Gerba believe that development of new technologies such as gene probes will allow routine monitoring of rotaviruses, Norwalk viruses, hepatitis A virus, *Cryptosporidium*, and *Giardia* [12]. Finally, consuming reused water presents risks of exposure to chemical contaminants (including organics, inorganics, suspended particulates, and radiochemicals), and suggestions for evaluation of these potential risks using laboratory animal tests have been provided by Neal [13].

General Studies of Factors Influencing Public Perception of Environmental Problems

Several studies have been conducted which have focused upon the identification of factors that influence public perception of risks related to environmental problems, although in many instances these studies encompassed environmental issues broader than water quality. Examples of factors that play a role in public perception of environmental pollution risks include demographic characteristics such as age, social class, rural versus urban setting, general political perspective, and sex.

For example, Hamilton has defined "technological catastrophes," in contrast to ordinary natural disasters, as follows: 1) resulting damage is unknown or invisible, 2) there is no clear low point, after which conditions will improve, and 3) they represent failure of systems which were once controlled by humans [14]. As a result, technological catastrophes are more likely to have widespread and long-lasting social impacts. Research on the Three Mile Island (TMI) accident established that those most concerned included the younger, more affluent, and better educated persons, particularly women, and especially women with small children. Case study reports of the Love Canal situation also indicated that the majority of antipollution activists were working class women, with older people less concerned than young persons. This is not surprising, as age indicates the stage of the family's life cycle. While there were fewer class-based effects than seen at Three Mile Island, similar age, sex, and parenthood patterns were noted.

Hamilton also conducted a mail survey of residents of a small New England town after the discovery of chlorinated hydrocarbons in the local water supply [14]. The findings of this survey included more concern on the part of more affluent residents, less concern by long-term or older residents, and the greatest degree of concern by women with young children. Men without children were most likely to think that the situation had been exaggerated. At one end of the spectrum of opinions were newer residents from higher-income households, particularly women with young children. At the other end were older, longer-term residents from poorer households, particularly males. Contrary to expectations, Hamilton did not find a correlation between the degree of concern and the two variables, education and age. Due to the number of independent variables which are highly correlated with each other, it becomes difficult to separate the effect of each. Hamilton suggested that it may be better to think of a "constellation of traits" which include age cohort, parenthood, and length of rural residence.

In an early study reported on in 1969, Ibsen and Ballweg summarized a survey of Montgomery County, Virginia, an area which was in transition from rural farms to urban residences, with a population over 50,000 persons [15]. The major activity was higher education. Telephonic interviews were conducted using a structured questionnaire (a technique which may obtain a sample that is not truly representative of the population due to nonlisting of telephone numbers, and not all homes having telephones). Personal and social characteristics which affected perceptions of water resource problems included gender, age, length of residency, home ownership, education, occupation, and income.

Outrage Factors

It has been noted by many authors that risk judgments often are based on factors other than the degree of hazard as identified by experts in the specific field. The examples cited in the previous subsection illustrate some of these factors. In fact, it has been theorized that judgments about risks are based on two components: hazard and outrage [16]. Hazard is the estimate of the probability of harm multiplied by the magnitude of the harm. Experts and technically oriented policy makers focus mainly on the degree of hazard. The public, however, may view actual hazards as of minimal importance. To the public, the "outrage components," such as whether the risk is voluntary or involuntary, familiar or unfamiliar, controlled by self or controlled by others, memorable or not memorable, dreaded or not dreaded, natural or unnatural, are the crux of risk judgments. A list of outrage factors and how they affect risk judgments is shown in Table 1 [17]. Some important outrage factors related to water quality have been identified by Scherer; these factors, described as follows, include some of the ones listed in Table 1:

- Process. When involved in all aspects of the decision-making process, the public often is willing to accept higher risk than when it is not involved in the decision-making.
- Control. There is a general feeling of safety associated with personal control. People who have private wells, for example, generally feel greater control and have more confidence in their water than do residents on central water systems.

Table 1. Effect of Outrage Factors on Risk Judgments [17]

Outrage Factor	Effect on Risk Judgments
Voluntary versus involuntary	Voluntary risks are considered less risky.
Natural versus unnatural	Natural risks are considered less risky.
Familiarity	Familiar risks are considered less risky.
Memorability	Memorable risks and risks tied to signal events (e.g., Love Canal) are considered more risky.
Dread	Risks with dreaded outcomes (e.g., cancer) are considered more risky than those with less dreaded outcomes (e.g., waterborne illness).
Known versus unknown	Risks that are well understood and can be reliably quantified are considered less risky than poorly understood risks.
Seat of control	Risks controlled by self are considered less risky than those controlled by others.
Fairness	Risks perceived as unfair are considered more risky than those perceived as fair.
Moral relevance	Morally relevant risks (e.g., pollution is not just bad, it is evil) are considered more risky than those that are not morally relevant.
Trust	If the institution causing or controlling the risk is not trusted, risk is considered to be higher than if the institution is trusted.
Process variables	If the decision-making process is seen as fair, with participation of all affected persons, risk is considered less than it would be if decisions were made without participation.

- Voluntariness. Risks that we choose to take generally are perceived as safer than risks forced upon us. Consider, for example, the difference between being required to drink water that you are told may contain a chemical pollutant, but for which there is no alternate supply, versus drinking water from an individual well from your home water tap.
- Fairness. One of the important issues in community water quality is often one of fairness. Consider residents living close to a landfill that potentially threatens ground water quality. Often it is argued that it is not fair that they suffer risk for the convenience of others. Even though the objective risk may be quite low, those residents tend to experience more outrage and, therefore, they perceive greater risk.

- Familiarity. More exotic risks tend to be regarded as more risky than familiar risks. Geologic radon, for example, tends to elicit little outrage, while the same hazard level of radon, when caused by industrial pollution, evokes high levels of outrage.
- Community history. Has the community had a history of risk-related problems? Were those situations resolved satisfactorily? If risk experts were to argue that there was a one-in-a-million chance of a waste management facility causing water pollution and then it happened, the public would be unlikely to believe future estimates.
- Social environment. The nature of the community clearly influences how residents will respond to potential threats. It has been noted, for example, that towns more responsive to adopting recommendations for ground water protection tended to be communities in a process of change, with an infusion of new residents and with slightly higher educational levels and more professional and managerial skills. These were the towns where residents questioned more, were more involved, and were more insistent that protective policies be established. Among the less-responsive towns, there was less concern for ground water protection, more emphasis on the effect protective policies would have on development, and a stronger emphasis on the status quo [16].

Slovic, Fischhoff, and Lichtenstein reported that perceptions of various water risks differ [18]. For example, factor analysis using dread and unknown risk factors has shown different perceptions for water risks such as water fluoridation, water chlorination, large dams, recreational boating, and home swimming pools. Water fluoridation and chlorination score high on the unknown risk factor (indicating that the risk they cause is difficult to determine, new, or has a delayed effect), but score low on the dread factor (indicating that the risk is controllable, individual in nature, and voluntary). Large dams present an opposite perception. The risks caused by large dams are perceived to be observable, old, and known to those exposed (low unknown risk factor score); however, they are also perceived as uncontrollable, affecting many people, and involuntary (high dread factor score). Home swimming pools and recreational boating risk perceptions score low on each factor. Research has also indicated that the higher a risk scores on the dread scale, the more people want to see strict regulation employed to achieve a desired reduction in risk. This is the case for all of the water risks, except fluoridation. Water fluoridation and chlorination have nearly identical dread factor scores, and yet people report a much greater desire that fluoridation be controlled with strict regulation. Though Slovic et al. do not discuss it, historically fluoridation has received more publicity than chlorination (as of the early 1980s when this study was accomplished), and perhaps this has led to a greater desire for its control.

Quiet Communities

An interesting study found in the literature review identified several factors that influenced one community to not overly respond to risk problems in the water environment. Ground water used as a water supply in the community has been contaminated with trichloroethylene (TCE), and the contamination sources appeared to be industrial employers within the community. Some cited reasons which led to a minimal public response (an inferred low risk perception) were as follows:

- There was an apparent general satisfaction with the activities and competence of both elected officials (city and county leaders and legislators) and appointed officials (health department and water and public works department employees). Additionally, elected officials and the relevant municipal staff were generous in their praise of each other and did not find fault with their respective efforts regarding the problem.
- Residents seem to have rested assured that their local leaders were taking care of them, that no one in the community was being harmed, and that there was nothing more for citizens to do. This sense of security and trust in their local officials acted as a major factor minimizing community anxiety over the health risk from TCE contamination.
- Another important explanation for the limited concern expressed about the health risk is that there was at the time no upsurge of unusual illness or other health effects, such as miscarriages or birth defects. No one publicly reported any health problems that seemed out of the ordinary or appeared linked to the TCE. So citizens went about their business, perceived the whole chemical contamination issue as temporary, and did not pay a great deal of attention to the question of health risks.
- Another set of factors minimizing public concern over the health risks had to do with the particular contaminant and its source. The chemical contaminating the ground water, TCE, was not unknown to local residents. On their jobs in local factories, men and women had handled and known about the degreasers that were used in several of the machining processes. Another aspect of this chemical was that people had not been able to see, smell, or taste it in their drinking water: only expensive, distant, and time-delayed laboratory tests could detect the presence of TCE in the water, even at the higher levels found locally. An additional factor is that the TCE that eventually reached the ground water had been used by local factories with local ownership or management and local workers. It appears that when the causes or agents of contamination are perceived as members of the community, the risks are less feared than when the causes or agents are perceived as external to the community.

- Anxiety or anger over the health risk was probably also minimized because the health risk statements that were given in public meetings were almost all probabilistic [19].

One-or-Two Factor Studies

A number of references were reviewed wherein one or two factors that influence risk perception related to water quality were identified. It should be noted that the studies to be cited may not have been focused on single factors per se; however, they represent specific key factors identified in the context of an overall study of water quality issues. Examples of such influencing single factors include the presence of a contaminant, whether a contaminant exceeds an established water quality standard, proximity of the individuals to the contamination problem, size of the community, and education and demographic factors [20-24].

Indirect influences also can be involved in the public perception of water quality risks; two examples in relation to a hazardous waste site and associated ground water contamination are unofficial risk messages and unintended risk messages. These examples are explained as follows:

- Unofficial risk messages—messages from other sources—the media, other experts, and nonexperts—often conflict with official risk messages. If an official risk message leaves people unsatisfied, they will seek and pay attention to other messages. Often these other messages come from totally unqualified sources, such as an uninformed media source, the person-on-the-street quoted in the local paper, the water-meter reader, a neighbor, or a relative. These unofficial messages, despite their questionable grounding in toxicology and their patent conflict with official messages, may sometimes find greater acceptance because they respond to the real questions people have and address their concerns more directly, and also because the unofficial messengers may be more trusted than the official messengers.
- Unintended risk messages—unintended messages about a risk often accompany and may contradict official messages. Mixed messages and conflicting messages occur because providers of information are not aware that communication of risk involves not only verbal (oral and written) messages but also behavioral and nonverbal messages. Interviews have made it clear that what official messengers do (or do not do) may be at least as important as what they say or write. In several cases, officials told a community not to worry but then sent in technicians dressed in "moonsuits" to gather soil samples from an area where children usually play. The wearing of moonsuits, a requirement of the Occupational Safety and Health Administration, was not explained to residents, leaving them to doubt the official statement that they need not worry. The frightening behavioral signals contradicted the calm of the verbal message.

It also appears that inactions may speak louder than words. In some cases the seemingly endless number of lengthy and expensive studies and investigations of the ground water problem, rather than quick action to remedy the situation, may heighten people's anxiety about a risk that was described to them as relatively serious; they worry that, while the studies are being conducted, they are still being exposed to the risk. However, in other cases the slow pace of official investigations may lead people to conclude that the risk must be quite minimal. In one community where an agency representative said there was an "imminent health hazard," the agency's failure to act in a timely manner contradicted its verbal message. As a mayor remarked, "If there really was a health problem, they would have closed us down years ago." Similarly, time delays in processing water test samples and informing local officials of the results are an unintended message that may contradict intended messages [25].

Risk Communication

An influencing factor in several of the studies previously mentioned is associated with the availability of information on the chemicals involved, the quality of the media, the sources of contamination, and the potential technologies which could be used in remediation programs. Accordingly, a major factor which influences public perception of water quality risk is the risk communication process. Risk communication can be defined as a process of interaction over time between senders and receivers of information about a risk [25]. In many instances, the problem that characterizes an attempt at a risk communication process is that there is no interaction phase.

Risk communication planning related to toxic chemicals in a community (and inferred actual or potential water quality problems) can be enhanced by realizing that risk communication should be looked at not only in terms of how accurate, detailed, or intelligible the information is, but also in terms of how the information will be interpreted. Specific points to be considered (as well as factors which influence the public perception of water quality risks) are:

- Reception of information about risk will vary from community to community, among various publics within any community, and through time. People's acceptance of the risk information they are given, while clearly affected by their attitudes about the risk itself, is also affected by the local context in which the risk situation is embedded. In addition, people perceive the message and the messenger as closely related—if the messenger is distrusted, the message may also be distrusted, no matter how accurate it may be.
- Receivers bring cultural assumptions and inputs of individual knowledge and experience to the communication interaction. The receiver inputs will act as filters, making it unlikely that there will be a one-to-one correspondence

between the message transmitted and the message actually received. What is said is not necessarily what is heard, and what is "correct" is not necessarily what is believed.

- Many messengers, both official and unofficial, are involved in presenting information to the public about a given risk. Lack of training and understanding of toxicology by most participants in risk communication may compound the problems of translating, conveying, and understanding highly technical risk information.
- Risk communication involves many risk messages. Frequently, unofficial or unintended messages mentioned in the previous sub-section may conflict with the official, intended message, thus causing interference with its reception [25].

As noted earlier in conjunction with outrage factors and as implied in considering education and risk communication, a major influencing factor associated with public perception of water quality risk appears to be the extent of uncertainty about the nature and extent of the problem, the characteristics of contaminating chemicals and their effects, and the strategies which might be available to remediate the problems. Three illustrations related to uncertainty and how this can influence risk perception are as follows:

- In a paper which dealt with methods to assess and manage risks associated with aquatic recreation, it was stressed that using risk analysis techniques to measure and predict risks associated with aquatic recreation was difficult. Further, it was noted that the public should be informed of the limitations which scientific and economic assumptions place on risk analysis [26].
- Because of scientific uncertainty with respect to health risks of dilute chemical concentrations in drinking water, there is a tendency to equate detection with risk [27].
- There are many scientific uncertainties about pesticides in ground water and this confuses the perception of risk, both from the science perspective and the public perspective. Examples of the uncertainties include chemical properties and their relationship to subsurface transport and fate, and human metabolic processes and resultant health effects.

Conclusions Related to Factors Affecting Risk Perceptions

Numerous opinion surveys have been conducted to solicit public information regarding perceptions of the severity of pollution problems and the need for societal responses. In many cases debates have arisen over the extent and magnitude of such pollutional concerns. For example, there is a continuing debate between the agricultural community and ground water regulatory program professionals regarding whether or not there are significant ground water contamination problems resulting from agricultural applications of fertilizers and pesticides. Obviously, one of the primary reasons for such debate is that the publics involved are influenced by different factors in different ways.

There have been few comprehensive studies specifically addressing factors that influence water risk perception. Risk perception and acceptable risk varies with disciplinary perspectives within the scientific community and with the perspectives of different publics and policy makers. Most of the literature on key factors relating to public perception of water environment risks tends to rely on the general theory and factors affecting risk perception. It has been found that many influencing factors on a range of societal risks, including various environmental problems, also have applicability to issues related to the water environment. What is lacking is a body of literature that specifically focuses upon factors influencing risk perception for the water environment. Several case studies have delineated factors associated with risk perception related to particular water environment concerns. Examples of outrage factors which influence risk perception include involvement in the decision making process, perception of personal control in exposure to the risk, voluntariness of exposure to the risk, fairness in terms of exposure to the risk, familiarity with the type of risk, history of the community in terms of environmental management and exposure to other related water risks, and the nature of the community in which the risk is being experienced. These outrage factors are not unique to the water environment.

Some communities are not overly concerned with regard to exposure to risk in the water environment. For example, in one case study the community exhibited relatively little concern over health risks, with the factors influencing this minimal expression of concern including the perception of no adverse health effects, the minor nuisance or dislocation related to the contamination, the non-ability to detect the contaminant with personal senses, familiarity with the key chemical of concern in the ground water, the perception that the origin of the contamination was internal to the community, and the perception that local officials were responding to the need and that they had a reputation of being competent and effective in protecting community health and well-being.

Additional problem issues that complicate risk perception related to water quality include the fact that the water environment is technically and scientifically complicated due to hydrodynamic considerations, chemical processes, and the kinetics of bacteriological decomposition. In many instances, the complexity of the water environment has to be greatly simplified in order to identify and assess potential water quality risks. Additional complicating factors are the uncertainties associated with risk identification and evaluation. Furthermore, there may be a non-personalization of water risk so that individuals do not see themselves as participants in causing contamination problems, nor do they necessarily envision themselves as being influenced by the water quality in their environs. Finally, another complicating factor is that conflicts may arise due to different perceptions of water risk, with conflicts existing between policy makers, scientific experts, public interest groups, the media, and individuals within the general public. These conflicts typically are associated with different perspectives on the nature and extent of acceptable water risks, and the benefits and costs related to responding to unacceptable risks.

OPPORTUNITIES FOR ENHANCING PUBLIC RISK PERCEPTION THROUGH RESEARCH

A fundamental need in relation to water quality and risk perception is for a basic conceptual model which can be utilized and tested in terms of the factors which influence public perceptions of water quality risks. The conceptual model should incorporate considerations related to both individual perception of risks as well as group perception of risks. Most studies which have been conducted on risk perception in general, or even related to certain aspects of water quality, have tended to focus on individual perceptions. For example, Covello, as quoted by Schwartz, White, and Hughes [28] noted the limitations of the literature after reviewing 166 books and articles on perception of risk and influencing factors. Covello stated that most of the studies focus on individual rather than group perceptions of risk, assuming that individual risk perception can be explained by psychological make-up, with little emphasis on organizational and social structural variables.

To further support the need for information on factors that influence both individual and group perception of risk, Fitchen has noted that risk perception is related to how each individual sees himself or herself in relation to the risk, and that people typically underperceive the effects of their own actions on other people's water [29]. To illustrate the former, the health risk posed by toxic chemicals is typically stated in terms of probabilities and aggregates (for example, as the number of excess cancers per million of population that would be expected from ingesting a certain amount of the chemical over a certain period of time). Fitchen noted that people interpret the risk as an individual issue, asking "What is *my* chance of getting cancer?" or "Should *I* drink the water?" There also are suspicions by various publics related to experts' statements regarding probability of health effects; these suspicions are not simply a failure in mathematical understanding, but a cultural phenomenon, or the conjunction of several cultural phenomena. The following traits could cause culturally generated interference with people's understanding of probability statements about health effects: 1) propensity to doubt experts, especially if their opinions differ from one's own or from each other's; 2) difficulty in perceiving collective health risk apart from the risk to the individual; 3) belief in personal immunity and, conversely, an alternative belief in personal susceptibility; and 4) cultural preferences for optimism and doing something about problems [29]. The underperception of the potential effects of individual actions on water resources may be a result of lack of understanding of environmental transport and fate processes.

Acceptability of Risk

There have been very few, if any, systematic studies conducted on the acceptability of water quality risk. Some studies have considered whether or not water quality standards might be exceeded, although as noted earlier, in some cases the mere presence of a chemical at some measurable concentration is sufficient to cause an increased risk perception. A fundamental need is to carefully define acceptable risk and delineate various causative factors or issues which should be considered. Some guides for determining an acceptable level of risk have been identified, and the following represents a non-inclusive listing:

- Reasonableness,
- Custom of usage (of the chemical for example),
- Prevailing professional practice,
- Best available practice, highest practicable protection, and lowest practicable exposure,
- Degree of necessity or benefit,
- No detectable adverse effect,
- Toxicologically insignificant levels, and
- The threshold principle (is there a known threshold or not in terms of health and/or ecological effects) [30].

Differences or Conflicts in Public Opinion or Perceptions

A fundamental issue of concern is related to the differences in public perceptions of risk as held by experts, elected officials, individuals in the general public, the media, and public interest groups. In many cases these individual collective publics have different information, and their perceptions of risk may be formed on the basis of different influencing factors. Accordingly, the fundamental model as identified earlier should address factors that influence risk perceptions by different publics.

Two specific types of publics can play a special role in influencing perceptions related to water quality risks: 1) public interest groups; and 2) the media. For example, public interest groups are considered to play a leading societal role in promoting the institutionalization of waste and toxics reduction, and by inference, the reduction or avoidance of water quality problems. They introduce the interests and concerns of citizens not included in the policymaking and program planning methodology of established corporate and political structures. Through the incorporation of values outside of traditional cost/benefit analysis, public interest groups can inform and expand the public debate. Public interest groups have been largely responsible for exploring public and private policy prospects for waste reduction and have since been instrumental in promoting its adoption as policy and practice [31].

Media can refer to written or electronic media. The literature on environmental hazards, including water quality concerns, suggests that media reports constitute a major source of information upon which people base their responses. When media coverage of a water quality problem increases, public concern increases; when media coverage wanes, public concern may decline [32]. However, the effect of media coverage on responses is neither direct nor simple. Variables such as prior experience, the responses of others, selectivity in attention, and various characteristics of the content of media reports interact to influence responses. On the basis of the extant literature on media and hazards, a model of the effect of media reports on the public's response to a natural hazard event has been developed. For example, a salt water intrusion in the Mississippi River that affected drinking water in the New Orleans metropolitan area in the summer of 1988 was studied [33]. The results suggested that in the absence of personal experience, people are more likely to respond to media reports regardless of personal relevance or seriousness of the consequences of the hazard events reported by the media. When people possess personal experience, they are more selective in their attention and response to media reports. The results also suggested that people use media reports of others' behaviors as cues to appropriate responses.

Use of Risk Information in Water Quality Policy and Individual Actions

Very little information exists on how public perceptions of water quality risks are actually used by policy makers in establishing public policy and in planning and implementing water quality management programs. An additional issue is associated with the responsiveness of different individuals to specific water risk information. In many cases the responsiveness of individuals is not directly related to how they perceive the risks.

For example, a study of individual responses to agricultural risk information has been conducted to determine the potential for voluntary adoption of management practices that reduce the risk of ground water contamination. Farmers' behavior and attitudes in Rockingham County, Virginia, and Big Spring Basin, Iowa, revealed that both groups consider the ground water issue to be a serious problem to which they are contributing [34]. This awareness is a significant first step in prompting consideration of management practices that reduce the threat to ground water quality. It was also found that the "worst offenders"—that is, farmers applying nitrogen well above agronomic recommendations—were those with the least concern about the problem. If major shifts in farming practices are to occur voluntarily, major incentives or disincentives are needed. Even though the concern about ground water quality is high, the documented risks perceived by farmers are not strongly convincing. The economic incentives for change are questionable at best. Voluntary adoption of best management practices is only one of several policy options. Ultimately, policies designed to reduce ground water contamination may need a mix of strategies, including economic incentives and disincentives, zoning and land use restrictions, environmental regulations, and bans on specific agricultural chemicals.

Conclusions Related to Research Needs for Enhancing Public Risk Perception

The assessment of the literature has indicated that only minimal specific research has been conducted on the factors which influence risk perception (risk acceptability) related to the water quality environment. More specifically, research is needed on pertinent factors influencing the scientific community, policy makers, public interest groups, and individuals in the general public. An overarching paradigm is needed to deal with both technological and natural risks and public perception and reaction. The aim of such research would be to develop a model which captures human behavior and which can be used to develop better water quality policies and make the risk assessment process more complete.

Some institutional barriers exist relative to communication of risk information. Examples of such barriers include the fact that governmental programs are often organized into a quality emphasis and a quantity emphasis. Individuals working on water quality issues oftentimes do not concurrently address quantity relationships, and vice versa. This conflict will be heightened by water quantity/availability issues forcing more water reclamation and reuse, with attendant decreases in water quality. In addition, risk related studies are often conducted with a narrow focus resulting from the perspectives of the disciplines involved and their own attention to issues of greatest familiarity. In many instances studies have limited focus and are not integrated with broader water quality relationships and policy perspectives, including implications of water quality changes on natural resources such as wetlands. A research emphasis could be on the role of institutional and interdisciplinary barriers in the development and transmission of information needed by policy makers and the general public in their formation of risk perceptions. Consideration could also be given to the degree that narrow disciplinary perspectives influence scientific and technical information communicated to policy makers and the general public.

There is very little literature which relates water quality risk perception to economic considerations related to the cost for remediation of water quality problems. In other words, risks are identified and perhaps prioritized without consideration being given to the remediation costs for reducing a specific risk. A broader concern is related to the relationships between economic growth and development and conflicts over water resources. A specific research focus could be to explore how policy makers and the general public consider economic development with respect to the risks associated with water quality, availability and conservation.

Examples of some additional research questions which could be explored are:

- How can the media, as a central player in the risk communication process relative to the environment, play a more balanced role in the risk communication process influencing water quality risk perceptions? Are there different or complementary functions or roles which could be played by electronic/ written media?
- Are questionnaire instruments effective tools to measure public perception of water quality risks? Does bias occur because people give "expected" answers? Are there other tools such as telephone surveys or panels which can be used to measure perception of water risks? Do these tools also have limitations?
- How can the role that scientific evidence plays in the risk communication process be improved? How can caveats and uncertainties about scientific evidence be better communicated to the public?
- Is there a role for pollution control and monitoring programs in decreasing water quality risk perceptions by various publics?
- How can risk perceptions related to water quality be used in long term planning for water resources development and quality/quantity management?

ACKNOWLEDGMENTS

The authors also acknowledge the multiple contributions of our colleagues: Dr. Tom James, Dr. Rageev Gowda, Dr. Elizabeth Gunn, and Ms. Nancy Hanks of the Science and Public Policy Program; and Ms. Leisa Davis of the Environmental and Ground Water Institute.

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