Risk Perception, Risk Communication, and Stakeholder Involvement for Biosolids Management and Research

Ned Beecher,* Ellen Harrison, Nora Goldstein, Mary McDaniel, Patrick Field, and Lawrence Susskind

ABSTRACT

An individual's perception of risk develops from his or her values, beliefs, and experiences. Social scientists have identified factors that affect perceptions of risk, such as whether the risk is knowable (uncertainty), voluntary (can the individual control exposure?), and equitable (how fairly is the risk distributed?). There are measurable differences in how technical experts and citizen stakeholders define and assess risk. Citizen knowledge and technical expertise are both relevant to assessing risk; thus, the 2002 National Research Council panel on biosolids recommended stakeholder involvement in biosolids risk assessments. A survey in 2002 identified some of the factors that influence an individual's perception of the risks involved in a neighbor's use of biosolids. Risk communication was developed to address the gap between experts and the public in knowledge of technical topics. Biosolids management and research may benefit from applications of current risk communication theory that emphasizes (i) *two-way* communications (dialogue); (ii) that the public has useful knowledge and concerns that need to be acknowledged; and (iii) that what may matter most is the credibility of the purveyor of information and the levels of trustworthiness, fairness, and respect that he or she (or the organization) demonstrates, which can require cultural change. Initial experiences in applying the dialogue and cultural change stages of risk communication theory—as well as consensus-building and joint fact-finding—to biosolids research suggest that future research outcomes can be made more useful to decision-makers and more credible to the broader public. Sharing control of the research process with diverse stakeholders can make research more focused, relevant, and widely understood.

The management of biosolids (treated municipal sewage sludge) is perceived and experienced by different people in different ways. The recycling of biosolids onto agricultural soils or for reclamation of depleted soils brings biosolids closer to more people, with the result that more people are becoming aware of biosolids and assessing whether or not they represent a risk to their health or the environment.

As biosolids recycling and other environmental programs have expanded in North America since the 1970s, there has been parallel growth in the social science understanding of how people learn, evaluate, and communicate about risks. These advances in understanding how risk is perceived and communicated have been applied in the health field and to environmental issues, such as hazardous waste management. However, they have been minimally integrated into the field of biosolids management.

Those involved in biosolids management have long recognized the importance of "public acceptance"—a sense of tacit public support for the concept and practice of biosolids recycling. In the 1980s, USEPA officials wrote about the importance of developing public support for biosolids recycling programs (e.g., Bastian, 1986) and a report on biosolids programs around the United States included recommendations that reflected limited social science understanding of how people develop their perceptions and understanding of biosolids (CH2M Hill and Consumer Concepts, Milwaukee, WI, unpublished report, circa 1982).

However, during the 1990s, most biosolids managers and the industry as a whole focused on gaining "public acceptance"; for example, biosolids management conferences almost always included sessions on "public acceptance." Emphasis was placed on education of the public about the scientific basis and experiences supporting biosolids recycling from the industry perspective (e.g., Powell Tate, 1993). Some concepts from social science research were brought into the field to improve public perceptions of biosolids. For example, the invention of the term "biosolids" was predicated on the understanding, verified by social science surveys, that it evokes a lesser negative response in many people than the word "sludge" (Powell Tate, 1993; Beecher et al., 2004). Risk perception and risk communication have been occasional topics at biosolids management conferences in recent years (Sandman, 2000).

The focus in the biosolids management field on gaining public acceptance of biosolids recycling mirrored the approach that many public agencies, public officials, and industries took in dealing with the public: the "Decide–Announce–Defend," or "DAD," approach. Biosolids management experts, like other experts in other fields, worked hard to convince the public that the decisions they were making were good decisions.

But members of the public are increasingly demanding involvement in decision-making processes—particularly those regarding public services like wastewater treatment and biosolids management (Monroe, 1990). In particular, citizens who are, or believe they may be, affected by decisions are unwilling to "leave it to the experts," especially to experts that have a stake in the outcome. This trend toward increased public involvement conflicts with the traditional "DAD" approach.

The "DAD" approach assumes that experts are the appropriate group to define, evaluate, and manage risks, an assumption that is now widely challenged. Experts are not always able to accurately assess risks; for example, not one of a group of internationally acclaimed geo-

N. Beecher, New England Biosolids and Residuals Association, P.O. Box 422, Tamworth, NH 03886. E. Harrison, Cornell Waste Management Institute, 100 Rice Hall, Cornell University, Ithaca, NY 14853-5601. N. Goldstein, *BioCycle*, 419 State Avenue, Emmaus, PA 18049. M. McDaniel, McDaniel Lambert, Inc., 1608 Pacific Avenue, Suite 201, Venice, CA 90291. P. Field and L. Susskind, Consensus Building Institute, 131 Mount Auburn Street, Cambridge, MA 02139. Received 2 Mar. 2004. *Corresponding author (Ned.Beecher@nebiosolids.org).

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677 S. Segoe Rd., Madison, WI 53711 USA

technical engineers, when asked to estimate within a 50% confidence limit the height of an embankment that would cause failure of a clay foundation, successfully estimated that value: some had estimates above the actual fail point, some below, but none of them made an estimate that included the observed fail point (Freudenburg, 1988). Bradbury (1989) noted that "since societal risk management decisions on the level, acceptability, and distribution of risk involve questions of values, and since differing values are held by those affected, risk management decisions must take into account the political, social and ethical, as well as technical, aspects of the policy problem."

This paper reviews how social science research on conflict resolution (Susskind and Cruikshank, 1987; Susskind and Field, 1996), risk perception, and risk communication exposes the pitfalls of the "DAD" approach and the danger of focusing on "gaining public acceptance." Evolving concepts of joint fact-finding and collaborative research and two recent experiences involving stakeholders in biosolids research are discussed. This paper applies social science theories specifically to the field of biosolids management, some aspects of which have met with considerable public concern and conflict. The same theories can be adapted and applied to the development of sustainable land application solutions for animal and industrial organic residuals, as well as other areas of public policy.

One note of caution: while increased communications and stakeholder involvement in biosolids and residuals management and research have the *potential* to reduce conflict, improve assessments of risk, and improve research outcomes, such outcomes are not certain and will depend on the levels of motivation, and commitment applied to developing methods of substantive communications and stakeholder involvement.

PERCEIVED RISK

In the late 20th century, the science and mathematics of risk assessment advanced dramatically, driven by needs in the environmental and public health fields to better understand the relative effects of various technologies and policies on human health and the environment. From the perspective of the technical risk analyst, risk is a concept that combines the probability of an occurrence of harm and the severity of that harm (International Organization for Standardization/International Electrotechnical Commission, 1999). In the 1970s, "investigators tried to establish general principles of public risk acceptability, usually based on mortality statistics and the de minimis risk principle, which argues that if a risk can be effectively lowered to less than one additional fatality per million citizens, the risk is effectively zero. Such an approach was uniformly unsuccessful, as evidenced in the nuclear industry" (Powell, 1996).

Beginning in the 1980s, social scientists noted that perception of risk is unique to each person and is rooted in our values, education, experiences, and stake in the outcome (Covello and Sandman, 2001; Douglas, 1992; Slovic, 1999). For example, someone who is familiar with a particular risk, someone we call an "expert," will have a different perception of the risk than someone less familiar with it. Thus, *familiarity* came to be understood to be a factor in how an individual perceives risk.

Social science research has since identified dozens of additional factors that affect how risk is *perceived* (Slovic, 1999; Covello and Sandman, 2001). Sandman (1987) called these "outrage factors," because they influence the level of concern, or *outrage*, that people feel regarding a real or potential hazard. He defined "risk" as the sum of "hazard" and "outrage" (risk = hazard + outrage), where "hazard" referred to the calculated probability of a dangerous event and its severity. A person's level of *outrage* is influenced by *outrage factors*. (Because Sandman's definition of "risk" is inconsistent with more common uses of the term "risk," this paper will refer to the sum of hazard and outrage as "perceived risk.") Everyone is influenced by outrage factors, including technical experts. In general, technical experts focus on estimating risk (what Sandman called "hazard") and do not consider outrage factors that contribute to perceived risk. The public, on the other hand, tends to pay less attention to the calculated hazard and are significantly influenced by outrage factors (Covello and Sandman, 2001).

Applying risk perception theory to the biosolids management field results in several striking findings. When the lists of outrage factors developed by social scientists (e.g., Covello and Sandman, 2001) are used to evaluate a land application scenario in North America, it is easy to see why biosolids recycling has seen greater conflict than other forms of organic residuals recycling (e.g., land applications of animal manure or yard waste compost). Many of the following outrage factors are involved, as neighbors and communities perceive a biosolids land application program to be:

- involuntary (out of their control),
- artificial and industrial,
- exotic and/or unfamiliar (manure is familiar, biosolids are not),
- hard to understand (not self-explanatory),
- memorable (because of odors or other nuisances),
- dreaded (the "yuck" factor of biosolids' origins creates dread),
- potentially catastrophic in time and space (issues raised about biosolids point to potential short- or long-term negative effects at the land application site),
- not reversible (e.g., persistent pollutants are permanent additions to soils),
- unknowable (there is a greater level of uncertainty regarding biosolids land application than regarding, for example, animal manures; biosolids have more diverse inputs from municipal sewers and so its constituents are more variable),
- having delayed effects (some effects from biosolids may not be evident immediately),
- affecting children and mothers (because they may happen to play around biosolids and/or consume foods grown on biosolids-amended fields),

- affecting future generations (because there is some uncertainty about long-term effects),
- having identifiable victims (reported cases of harm to cows and people),
- potentially affecting them such that they have a personal stake (neighbors who believe they are affected),
- being controlled by "the system" or others,
- unfair ("the farmer gets the benefits and the neighbor only gets some added risk"),
- morally and/or ethically objectionable (if biosolids are seen as a potential threat, then it can be perceived as morally wrong for powerful cities to foist biosolids on a rural community),
- associated with untrustworthy people (social science surveys have most often shown that government officials, people from out of town, and those who have a financial interest are perceived as less trustworthy),
- operating by a closed process (communities around land application sites too often find the process closed and difficult to understand),
- having more media attention (media stories about a biosolids project heighten local interest and, if they report opposition, public concern tends to increase), and
- having limited or no visible benefits (land application occurs far from the wastewater facility and in communities that perceive little benefit to them).

Outrage is further influenced by who communicates the issues and how they do so. For example, some surveys (Sheldon, 1996) have found that female communicators may be perceived as more trustworthy. Yet, traditionally, the biosolids field has been dominated by men. In the biosolids debate at the national level, many of the more vocal concerned citizens are women who may have no personal stake in the outcome and are, therefore, perceived by the public as more trustworthy. Add to this the fact that "men tend to judge risks as smaller and less problematic than do women" (Slovic, 1999), so many of those managing and regulating biosolids may, in general, be less sensitive to risks.

Applying risk perception theory can be crucial for biosolids managers to better understand the diversity of reactions they can expect to encounter as they interact with the public regarding biosolids. It also helps in understanding the effects of their speech and actions on the perception of risk. For example, biosolids managers tend to reduce the perception of risk, consciously or not, by using arguments that remove outrage factors or reduce their intensity: "Biosolids are widely used, well-understood, natural, recycled products that are necessary by-products of public wastewater treatment programs." Those most vocally concerned about biosolids recycling tend to increase the perception of risk by using arguments, consciously or not, that maximize outrage factors: "Sludge is an unknown, toxic soup full of industrial wastes." Conscious consideration of all outrage factors affecting a particular situation can help biosolids managers address those outrage factors that are more likely to be overlooked; for example, as Covello and Sandman (2001) point out, "making a risk fairer, and more voluntary (etc.) does indeed make the [perceived] risk smaller."

Uncertainty is an outrage factor that plays a particularly important role with regard to biosolids recycling (Beecher et al., 2004). "People are averse to uncertainty. . . . This aversion often translates into marked preference for statements of fact over statements of probability—the language of risk assessment" (Covello and Sandman, 2001). Add to this the fact that some surveys (e.g., a 1994 Harris poll and work of Swazey et al. as reported in Powell, 1996) indicate a decline in public trust in technology. Occasional media reports of scientific fraud or violations of ethics add to this public skepticism and sense of uncertainty. With regards to biosolids, uncertainty is further increased by the lack of an accepted, shared definition, from one location to another, of what are "safe" standards for land application; the existence of some poorly run programs; and some history of negative press coverage.

Public perceptions of biosolids recycling were measured in a telephone survey of 1069 homeowners and house renters across the United States in 2002 (Beecher et al., 2004). This survey found that support for the concept of wastewater treatment is high (93%, with a survey margin of error in the range of 3–5%). At the same time, knowledge of the word "biosolids" is limited (14%). When explained to survey respondents, the *concept* of biosolids recycling is supported, although the respondents were quick to express some uncertainty around particular issues such as "heavy metals." They also expressed a need for more information and more time to personally assess risks and benefits. In seeking more information, survey respondents said they would initially turn to and trust friends and neighbors, government agencies, and academic researchers.

Responses to the outrage factors that were tested in the 2002 biosolids perception survey closely reflected those predicted by risk perception theory. For example:

- respondents favored biosolids recycling programs that display clear benefits, such as providing renewable energy or recycling of nutrients;
- their level of concern increases if biosolids include industrial waste sources or are from a large city;
- their level of concern decreases if they are contacted about the biosolids recycling program in advance and/or if it is supervised locally (reducing uncertainty); and
- respondents expressed trust in those who appear most knowledgeable and objective and strongly distrust those who have a profit motive.

The concept of perceived risk has become widely accepted. However, its implications continue to be explored. For example, Slovic (1999) noted that, inevitably, the process of risk assessment is influenced by the risk assessors' values, education, experiences, and, possibly, stake in the outcome. Therefore, citizen knowledge and technical expertise are both valuable in developing a more useful and balanced assessment of risk and perceived risk. Covello and Sandman (2001) note: "Discussions of risk may also be debates about values, accountability, and control."

RISK COMMUNICATION

Risk communication is a specialized field of communications, a response to the needs of those who wished to bridge the gap between the knowledge of the experts and of the general public on technical topics. Properly applied, risk communication can help people with differing perspectives and levels of expertise to share a common understanding of the level of risk (actual danger) involved in a particular activity. Sometimes, risk communication techniques are applied with the intent of increasing the level of concern and heightening the perception of risk, such as when a public health agency wishes to increase public response to a risk such as radon in indoor air. At other times, risk communication is used with the intent of decreasing the level of concern and decreasing the perception of risk, such as when the level of concern about a new technology is thought to be higher than the *communicator* believes is warranted based on his or her understanding of the hazard (of course, the communicator's assessment of the risk may be skewed by his or her personal perception, experience, or stake in the outcome, and some such uses of risk communications can be seen as manipulative). To change the perceived level of risk, risk communication strives to change the number and intensity of outrage factors (Covello and Sandman, 2001).

Risk communication is not intended to be a substitute for risk management. It is not intended to be a way of hiding something or manipulating opinions. Rather, its aim is to ensure that a diverse range of people share a common, accurate understanding of the level of risk so as to ensure "policy decisions and public discussion based on the best information available" (Powell, 1996). "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" (National Research Council, 1989).

Covello and Sandman (2001) describe four stages of risk communication:

(i) Ignore the public—this was common before the mid-1980s;
(ii) Improve explanations of data, especially data regarding risk—this, if used alone, is usually part of the "Decide–Announce–Defend (DAD)" approach;
(iii) Engage in dialogue—two way communications and sharing of information and understanding; and
(iv) Affect change in individual and/or organizational values and culture.

To date, biosolids managers have mostly focused their communications efforts on gaining public acceptance by utilizing just the second stage of risk communication. They have believed that they have the best information and the most expertise, therefore all that is needed to attain agreement is to educate the public. Furthermore, they have perceived that their work is for the public good. They focus on improving how and what is communicated, tailoring presentations to the audience, and improving explanations of technical information. Often, this approach has failed, largely for two reasons: (i) it ignores the fact that differences in perceptions and opinions regarding biosolids recycling are rooted in the diversity of people's values and beliefs, and (ii) it only utilizes one-way communications. Sometimes, this approach has caused more harm than good, because it can be perceived as dismissive and arrogant.

Deeper conflicts regarding biosolids management are usually not resolved by traditional one-way communications. Rather, they tend to become entrenched, with people stuck in their widely divergent positions. However, if dialogue—the third stage of risk communication—occurs, some softening of conflict becomes possible, even if significant differences of opinion remain. Many organizations and individuals in diverse fields, including biosolids management, are better developing their abilities to establish dialogue around key issues.

As individuals and organizations share more information and undertake dialogue with diverse stakeholders and the general public, they often come to see the need for a significant change in values and organizational culture (stage four of risk communication). This change is substantial and involves the concept that "strategies for building consent differ significantly from tactics for minimizing the opposition" (Potapchuk, 1991). At the beginning of the 21st century, this is the "cutting edge" of risk communication efforts: stages two, three, and four build on each other and are necessary to maximize the effectiveness of risk communication (Covello and Sandman, 2001).

To create the necessary climate and culture for stage four risk communication—for widespread dialogue in organizations and an entire field, such as biosolids management—there are obstacles to be overcome (Covello and Sandman, 2001). These include:

- the fact that technical experts tend to like clear boundaries and logic, not emotion;
- the belief that the public is irrational;
- discomfort with empowering the public by bringing them into the decision-making process;
- the belief of those working on an environmental management problem that they are doing good and should not be challenged so much by different kinds of information and opinions;
- the personal discomfort that comes with significant change; and
- the level of personal and/or organizational commitment required to make significant change.

The authors have observed numerous examples and heard many statements of these obstacles in the biosolids management field.

STAKEHOLDER INVOLVEMENT

The biosolids management field is beginning to experiment with the third and fourth stages of risk communication. It is becoming more widely recognized that "people care about the decisions you make, but they care even more about the process you used along the way" (Kim and Mauborgne, 2003). A National Research Council panel on biosolids recommended stakeholder involvement in biosolids risk assessments (National Research Council, 2002a). Thus, there are increasing efforts by biosolids managers to inform people who may be affected, explain how decisions are being made, and include stakeholders in decision-making. Communications and public participation in biosolids management programs have gained heightened importance, including formal incorporation into the U.S. National Biosolids Partnership's Environmental Management System for Biosolids (National Biosolids Partnership, 2002).

The interest in improved dialogue and collaboration with the public is also extending into research on contentious aspects of biosolids management. The Water Environment Research Foundation (WERF) sponsored two social science studies on public perception and participation regarding water reuse (Hartley, 2003) and biosolids management (Beecher et al., 2004). Applying the findings of these projects to its own research processes, in July of 2003, WERF convened a three-day "biosolids research summit" of diverse stakeholders. It included neighbors to sites who report illnesses they attribute to biosolids application and local officials from communities seeking to restrict application. More than 170 attendees discussed research needs and helped set a research agenda for biosolids. Also in 2003, diverse stakeholders were brought into the development and implementation of a field research project regarding air emissions from biosolids land application.

The WERF research summit was credited with having achieved improved mutual understanding and a relatively fair process (Beecher, unpublished data, 2004). In contrast, the air emissions research project process, facilitated in part by one of the authors, did not include diverse stakeholders *from the beginning* of the project and involved them in only some decisions, thus it has been viewed by the public stakeholders as less fair and credible. The research summit has led to follow-on efforts and projects.

Scientific research has traditionally been a process conducted by one or a few technical experts who are detached from the issues and the diversity of stakeholders. Depending on how different researchers frame research questions and make assumptions and decisions, the outcomes of similar research can be significantly different. When fed into a contentious debate, such as that about biosolids recycling, these differing outcomes confuse the public, increase uncertainty and distrust in science, and lead to conflict. Those in conflict over the issue choose studies and scientists who, they feel, support their positions. One scientist's facts, no matter how well technically supported, may not be considered credible by all stakeholders, because interpretations of data and a study's limitations legitimately vary. Without shared understanding of a study's analysis, assumptions, interpretations, and limitations, the public has no way of fairly comparing one study with another. The end result is usually that one expert supporting a particular conclusion is challenged by another expert that the public perceives as equally credible. This scenario has played out numerous times in biosolids management debates (e.g., Gaskin et al., 2002).

In addition, those expressing concerns about biosolids recycling believe that much biosolids research has been supported by entities with a real or perceived stake in the outcome of that research (i.e., wastewater treatment facilities or private land application contractors seeking to efficiently dispose of biosolids). This has led to particular distrust of some research outcomes. The source of this distrust may be largely attributable to the source of research funding, which, in several studies of research (mostly in the medical field), has been found to be a significant predictor of research outcome (Bodenheimer, 2000; Cho and Bero, 1996; Friedberg et al., 1999; van Kolfschooten, 2002).

In response to the distrust and confusion created by dueling science in public policy conflicts, social scientists have developed cooperative processes for integrating technical knowledge into policy and action. These include "joint fact-finding," "collaborative research," and "citizen science"—the definitions of which can blur in practice. What these approaches share is that they bring together multiple, diverse stakeholders in knowledge-gathering and scientific inquiries. They include recognition that environmental issues, such as biosolids management, are complex and multidisciplinary and need to be addressed with a diversity of perspectives and expertise.

Joint fact-finding (Ehrmann and Stinson, 1999; Conflict Resource Consortium, 1998) usually involves the cooperative collection and review of data and information by diverse stakeholders. It aims to create a common pool of knowledge that all stakeholders are more likely to find credible and useful. It most often involves compiling existing scientific data and findings and coming to agreement on mutually acceptable information. It may or may not include conducting actual new research studies. Collaborative research (Lasker and Weiss, 2003) involves cooperation among several investigators in the primary scientific research process. Citizen science refers to the involvement of people who are not professional research scientists in the collection of data. Each of these processes provides opportunities for scientists to understand and incorporate concerns of diverse stakeholders. Each approach can allow for the incorporation of local, sometimes nontechnical, knowledge, while giving appropriate weight to the scientific knowledge of technical experts.

In a joint fact-finding or collaborative research effort, stakeholders may work together to jointly understand the problem, develop the research question(s) and/or hypothesis(es), develop the methodology, gather data, analyze data, draw conclusions, and communicate results. While joint fact-finding or collaborative research usually take more time, effort, and money than traditional research processes, they can help avoid delays and costs that accrue when conflict erupts over science-intensive policy decisions.

The effectiveness of this kind of stakeholder involvement *in research* has not been evaluated much, if any, by objective studies. And there are only a few studies that evaluate collaborative efforts (Lasker and Weiss, 2003) or stakeholder involvement in addressing *policy disputes*, mostly because it is difficult to measure and make comparisons regarding what might have happened if a collaborative process had *not* been undertaken. In 2001, the USEPA released an evaluation of "stakeholder involvement and public participation" that provides some lessons learned within the agency (USEPA, 2001) regarding stakeholder involvement in addressing policy disputes. In addition, a current National Research Council panel is attempting to evaluate the effectiveness of different models for public participation in policy decisions and what the common critical elements are (National Research Council study of public participation in environmental assessment and decision making, personal communication, 2003).

Those involved in nascent efforts to involve stakeholders in the design and oversight of research regarding biosolids management have provided mixed anecdotal reviews. Some of the involved scientists find the intense communication and extended time frame required of such efforts to be cumbersome and frustrating. Other scientists have found value in improvements to research questions and methodologies resulting from diverse stakeholder involvement. Likewise, nontraditional stakeholders have reported both frustration with the process and appreciation for the efforts at inclusion. Additional work, led by WERF, is being done to improve the efficiency, usefulness, and fairness of stakeholder involvement in designing and overseeing research on biosolids, wastewater management, and related topics.

As noted above, one critical consideration is how funding for research flows: who provides it and how it is managed. In the biosolids management debate, concerned citizens have expressed skepticism regarding the findings of research funded by those with a financial stake in the outcome. To avoid this credibility problem, it may be necessary to develop a new mechanism for managing funding. Further, as learned from the ongoing collaborative research effort investigating airborne emissions from biosolids land application sites, it is important to involve a diverse group from the start—including not only scientists, but also people with local, "real-world" experience (including biosolids managers and site neighbors). Working together, this diverse group of stakeholders defines the research agenda, design, and protocols; selects the research team; and agrees on the limitations imposed by the study design and scope. These are not conditions under which all scientific research should be conducted, but when facing dueling scientific experts and challenges to the credibility of research outcomes—as has happened in some aspects of the biosolids recycling field—this approach, more cumbersome as it is, becomes necessary.

The experiments with joint fact-finding and collaborative research in the biosolids field are occurring at a time when public interest research and the role of science and research in society are topics of discussion in many fields (Lubchenko, 1998). The discussion includes what makes science most useful to society and most applicable to real-world problems. For example, Cash et al. (2003) propose that "science with impact" involves three key aspects: it must be credible, legitimate, and salient.

The *credibility* of research derives from the scientific adequacy of technical evidence and argument (Cash et al., 2003):

- good data derived with quality assurance,
- good methods that are acceptable to peers and are reproducible,
- good analysis that yields reasonable findings rationally explained from the data, and
- conclusions that are defensible and reasonable and the limitations of which are clearly acknowledged.

In short, credibility is enhanced by stressing integrity in research (National Research Council, 2002b).

Legitimate research is created through attention to the way in which it is conducted. People perceive a research effort as legitimate if the production of the information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests (Cash et al., 2003).

Salient research is most useful to the variety of stakeholders. It is relevant to the needs of decision-makers and other users of the information. It answers meaningful questions, can be put to use by various stakeholders, and it informs, shapes, and frames decision-making (Cash et al., 2003).

There has been extensive research in the field of biosolids management, more than thirty years. Yet public conflict continues and some concerned stakeholders distrust some or much of the existing research. As one scientist involved in biosolids research noted, "having completed a thousand studies, what makes us think that the 1001st study will convince skeptics?" Biosolids research and policy decision-making could benefit from applying the concepts of joint fact-finding, collaborative research, and other forms of stakeholder involvement.

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REFERENCES

Bastian, R. 1986. Institutional barriers to technological innovation in municipal wastewater and sludge management practices. *In* K.D. Stolzenbach, J.T. Kildow, and E.T. Harding (ed.) Public waste management and the ocean choice. MITSG 85-36. Massachusetts Inst. of Technol. Sea Grant College Program, Cambridge, MA.

Beecher, N., B. Connell, E. Epstein, J. Filtz, N. Goldstein, and M. Lono. 2004. Public perception of biosolids recycling: Developing public participation and earning trust. Water Environ. Res. Foundation, Alexandria, VA (in press).

Bodenheimer, T. 2000. Uneasy alliance: Clinical investigators and the pharmaceutical industry. N. Engl. J. Med. 342:1539–1544.

Bradbury, J.A. 1989. The policy implications of differing concepts of risk. Sci. Technol. Hum. Values 14:380–399.

Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jager, and R.B. Mitchell. 2003. Knowledge systems for sustainable development. Proc. Natl. Acad. Sci. USA 100:8086–8091.

Cho, M.K., and L.A. Bero. 1996. The quality of drug studies published in symposium proceedings. Ann. Intern. Med. 124:485–489.

Conflict Resource Consortium. 1998. Joint fact-finding and data mediation [Online]. Available at www.colorado.edu/conflict/peace/treatment/jfactf.htm (verified 3 Aug. 2004). Univ. of Colorado, Boulder.

Covello, V., and P. Sandman. 2001. Risk communication: Evolution and revolution. p. 164–178. *In* A. Wolbarst (ed.) Solutions to an environment in peril. Johns Hopkins Univ. Press, Baltimore.

Douglas, M. 1992. Risk and blame (essay). *In* Risk and blame: Essays in cultural theory. Routledge, London.

Ehrmann, J.R., and B.L. Stinson. 1999. Joint fact-finding and the use of technical experts. p. 375–400. *In* L. Susskind, S. McKearnan, and J. Thomas-Larmer (ed.) The consensus building handbook: A comprehensive guide to reaching agreement. SAGE Publ., Thousand Oaks, CA.

Freudenburg, W.R. 1988. Perceived risk, real risk: Social science and the art of probabilistic risk assessment. Science (Washington, DC) 242:44–49.

Friedberg, M., B. Saffran, T.J. Stinson, W. Nelson, and C.L. Bennett. 1999. Evaluation of conflict of interest in economic analyses of new drugs used in oncology. JAMA 282:1453–1457.

Gaskin, J.W., D.K. Gattie, L.M. Risse, E.W. Tollner, P.G. Hartel, W.P. Miller, and D.L. Lewis. 2002. Land-applied Class B biosolids: Putting human health risks in perspective. Georgia Water and Pollut. Control Assoc., Marietta.

Hartley, T.W. 2003. Water reuse: Understanding public perception and participation. Water Environ. Res. Foundation, Alexandria, VA.

International Organization for Standardization/International Electrotechnical Commission. 1999. Guide 51. ISO/IEC, Genva.

Kim, W.C., and R. Mauborgne. 2003. Fair process: Managing in the knowledge environment. Motivating People. January, p. 127–136.

Lasker, R.D., and E.S. Weiss. 2003. Broadening participation in community problem solving: A multidisciplinary model to support collaborative practice and research. J. Urban Health 80:14–60.

Lubchenko, J. 1998. Entering the century of the environment: A new social contract for science. Science (Washington, DC) 279:491–497.

Monroe, J.A. 1990. The democratic wish: Popular participation and the limits of American government. Basic Books, New York.

National Biosolids Partnership. 2002. Elements of an environmental management system (EMS) for biosolids. Final interim draft. Natl. Biosolids Partnership, Alexandria, VA.

National Research Council. 1989. Improving risk communication. Natl. Academy of Sci., Washington, DC.

National Research Council. 2002a. Biosolids applied to land: Advancing standards and practice. Natl. Academy of Sci., Washington, DC.

National Research Council. 2002b. Integrity in scientific research: Creating an environment that promotes responsible conduct. Natl. Academy of Sci., Washington, DC.

Potapchuk, W.R. 1991. New approaches to citizen participation. Nat. Civic Rev. 89:158–168.

Powell, D. 1996. An introduction to risk communication and the perception of risk [Online]. Available at www.foodsafetynetwork.ca/risk/risk-review/risk-review.htm (verified 3 Aug. 2004). Univ. of Guelph, Guelph, ON, Canada.

Powell Tate. 1993. Communications plan on biosolids. Water Environ. Federation, Alexandria, VA.

Sandman, P. 2000. Dealing with outrage: A key communication tool for biosolids professionals. Water Environ. Federation, Alexandria, VA.

Sandman, P.M. 1987. Communicating risks: Some basics. Health Environ. Dig. 1(11):3–4.

Sheldon, K. 1996. Credibility is risky business: An interview with Vincent T. Covello, Ph.D. Commun. World 13.

Slovic, P. 1999. Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. Risk Anal. 19:689–701.

Susskind, L., and J. Cruikshank. 1987. Breaking the impasse: Consensual approaches to resolving public disputes. Basic Books, New York.

Susskind, L., and P. Field. 1996. Dealing with an angry public: The mutual gains approach to solving public disputes. The Free Press, New York.

USEPA. 2001. Stakeholder involvement & public participation at the U.S. EPA: Lessons learned, barriers, & innovative approaches. USEPA, Office of Policy, Economics, and Innovation, Washington, DC.

Van Kolfschooten, F. 2002. Can you believe what you read? Nature (London) 416:360–363.