IS THERE A PARADOX IN TRANSLATING SCIENCE AND TECHNOLOGY INTO THE DECISION-MAKING PROCESS?

Ronald B. Linsky

Executive Director
National Water Research Institute

Since the appearance in 1962 of the now questionable publication *Silent Spring* by Rachael Carson, our society has been rapidly evolving into one characterized as environmentally aware, but litigious and confrontational in nature. "For the first time in the history of the world," she asserted in her book "every human being is now subjected to contact with dangerous chemicals from moment of conception until death." Her assertion is absolutely not true. Significant research during the last 40 years has clearly demonstrated the vast bulk of the chemicals humans are exposed to are natural, and according to Bruce Ames and Lisa Gold, cancer researchers at the University of California Berkeley, a certain amount of every chemical is going to be dangerous. Ames and Gold also pointed out that 99.9 percent of the pesticides consumed by humans naturally occur in plants to ward off their insect enemies.

The impacts of changes evolving over the last four decades upon science and engineering, research and researchers, and decision makers and the decision making process have, in my opinion, become a paradox. In essence, the real question is whether or not there is value in translating science and technology, or the results of research, into the decision-making process.

You may have observed or experienced the full array of what can be termed environmental emotionalism of the last thirty years. And many may have observed the results of poorly trained elementary and secondary students by educators who teach young minds a significant amount of pseudo-science and ecology. My own experience in this matter stems from the fact that the National Water Research Institute has provided prize money to science fair winners in California, Delaware, New Jersey, and Pennsylvania for the last ten years. Over this period, I have found that more and more students who enter their projects in the fairs were told in the beginning the results they should create in order to support a particular viewpoint or that would be favorable to one or another of the popular local environmental groups, such as Green Peace or National Resources Defense Fund. A case in point was when a young student submitted a project reporting that he collected and identified the indicator bacteria, *E. coli*, from stormwater samples. He concluded that sewage spills from a local treatment plant were the source. When asked to identity the location of the treatment plant, he said that his teacher told him it was in the immediate area where he collected the samples. However, when told there were no treatment plants within a several mile radius of his sample sites, he was at a loss to understand why his teacher told him differently. Coincident with the collection of data and the preparation with his project report, several local groups had been campaigning against ocean pollution from urban runoff. This was evident in the media for many months prior to the Fair. He did stand firmly, however, on the "fact" that *E. coli* was present in his samples and therefore the pollution had to be of human origin and therefore humans were the cause of the contamination. When further discussions indicated that the particular indicator organism could also be found in other warm blooded organisms (e.g. dogs, cats, possums, coyotes), the information was new and rather startling inasmuch as his teacher told him that the bacteria only came from man.

Science literacy has been and will continue to be a major contributor to the paradox. Citizens' interests in science often exceed their grasp. Despite all the good intentions of the educational enterprise, the average public just does not know much about science. A survey conducted in 1998 by the National Science Foundation indicated that 79 percent of American adults agreed or strongly agreed that basic scientific research is important and should be sponsored by the federal government. When asked a series of fundamental science questions, the average score for the 2,000 adults in the survey was only 55 percent correct. Another element of the survey indicated that 70 percent had a high interest in medical research but only 52 percent were interested in environmental issues. Examples of correctly answered questions were: Is the center of the Earth is very hot? (True) 82 percent. Do lasers work by focusing sound waves? (False) 39 percent. Does cigarette smoking cause lung cancer? (True) 93 percent. In your own words, what is a molecule? (Smallest particle of an element or chemical compound that retains the characteristics of the element or compound.) Eleven percent of those questioned correctly responded with a closely allied answer.

And too, many of you have no doubt observed or interacted with the plethora of instant scientists, engineers, and lawyers, who may have read *Silent Spring* or similar publications. We have also seen the Emersonian perspective of the environment take on a new form of radical environmental activism that has no qualms at "taking out" a research laboratory and the extensive intellectual investment to make a particular point regardless of the fact that the results of such research can save lives and improve the quality of life for millions of people around the world. There has also been a growth of pseudo research that is used as a political tool to convince minds of a particular point of view.

This evolving trend was bolstered in the early 1970's by the growing vanguard of "wannabes," the people looking for a cause to justify their existence that reflected the radical nature of the citizenry of the period. The nation soon developed an environmental lexicon. Words like *environmentalism*, *environmental justice*, and soon the *environmental advocate and environmentalist* became the spokespersons for all things pertaining to the environment. These terms more often made people feel good and set them apart in the perception of the broader population than they added value to real issues and problem-solving. During this decade, the holistic concept of the environment was in the beginning perceived as essential and a noble cause by the general public. However, it soon became obvious that all was not well with the interpretation of environmental affairs. Citizen environmentalists were beginning to be recognized by the news media as "real experts" because they "believed in the environmental issues" and were not associated with government or with the other enemy, corporations. Of course that perspective helped to sell papers too. It took only a few short years before the "environmentalist" became recognized as *the* experts when it came to scientific and technical issues. At the same time, the term *environment* began to take on an almost mystical druid-like connotation. Belief in things environmental was rapidly becoming a part of our society, competing with cultural ethics and religions.

During this period, which was hailed by some as the environmental revolution, another phenomenon was emerging that saw credible scientists and engineers being subpoenaed to testify in courts of law as to the right or wrong, black or white, or good or bad of a particular scientific or technical principle.

In rapid succession, the integrity of scientists, and ultimately research, began to erode in deference to favorable outcomes for either the plaintiff or defendant, not the discovery of truth.

A direct outgrowth of these events was the development of a new American industry, the expert witness. As the number of "experts" grew, so did the fees paid to them. In the courtroom setting, expert witnesses, whether or not they were experts in the field, became, in the eyes of those present and the general public, scientific or technical experts. Eventually, this new industry created a cadre of what can be termed professional expert witnesses. Soon, it was obvious that if you had a doctorate in anything you could enter the game. Research began to deteriorate from what was, in my opinion, a creative process of discovering new knowledge based on human curiosity, into a premeditated cookbook approach. Research was beginning to be reduced to a process that prescribed the results to create a win or defeat as the legal case dictated. Scientific truth was being manipulated to create doubt, half-truths or denial. The doctorate is not an expert in everything. However, those persons called as expert witnesses to testify were selected more because they had an advanced degree in something rather than the knowledge that the advanced degree theoretically represents.

As a result, the perception of a scientist or researcher in America has eroded during the last several decades; their image has been often confused or relegated to that of an environmental police or, like that of the U.S. Environmental Protection Agency, an enforcer. The perception that they are a part of a problem-solving team is now significantly limited.

Another new and evolving business emerged during this same period and has now reached a new level of refinement. You can find it today in the employment section of your local newspaper under the column titled Activism. There you will find ads for part-time employment as an activist for such organizations as the Sierra Club and Green Peace. You can earn up to $8,000 a summer as a part-timer just like any other summer job in construction or clerical work. It no longer matters if you have strong emotional feelings about the issues. You now can earn real money and, therefore, what was in the beginning a passion is now modified to simple economics.

The 1970's also brought a mix of events, happenings, and publications that contributed to the further erosion of the credibility of scientists and researchers. Many were created by credible scientists and researchers themselves and based too often on the emotionalism of the period. One of these was the publication of Paul Ehrlich's book, *The Population Bomb* in 1968. Ehrlich predicted: "In the 1970's hundreds of millions of people are going to starve to death." Overpopulation, he claimed, would overwhelm the food supply. It did not

happen. World population has more than doubled since 1950, but food supplies have more than tripled. Life expectancy of the global population has risen from 46.5 years in 1950 to more than 64 years today. This represents the greatest increase in human welfare in history. If this trend continues, we will have more than eight billion people on earth by the year 2040. Can we feed all these people? Absolutely! Improvement of crop yield will more than take care of the population needs by then. As a result of improved crop yields, the area used to grow crops, about three billion acres globally, has increased little in the last two decades.

Other purported science-based elements have also been significant contributors to the paradox. Think of the numerous advertisements that have offered "scientific" proof of their products' worthiness. Canada Dry Sparkling Water is stated to have "pinpoint carbonation," yet to date no one has been able to discovery what this is. Deodorants that advertise the use of chlorophyll as the active ingredient are interesting too. The original patents of some of these products indicate that a great many molecules of formaldehyde are used to "activate" a very few molecules of chlorophyll. Because it takes so many molecules of formaldehyde to activate the chlorophyll, one is reminded of the embalming process.

As the evolution of the paradox continued over the next two decades, one begins to observe that research science is permeating beyond environmental activism and into the arena of criminal and civil law. The world sat on the edge of their chairs when exposed through daily television to an introduction into the rudiments of the polymerase chain reaction (PCR) through the drama of criminal court proceedings. It would be interesting to examine the sensational trials of the last decade to see if support for the genome project could be traced to such televised trials. Ten's of millions of people saw the seemingly endless trial with its mini-courses in genetics and biochemistry. Wouldn't it be wonderful if students would be attentive!

Along the road to the 21st Century, bad science too has contributed measurably to the paradox. The inability of the media to discern reasonable science from unreasonable science has contributed markedly to the erosion of the credibility of research.

In 1983, the noted astronomer and television personality Carl Sagan co-authored an article in *Science*, the journal of the American Advancement of Science Society, introducing the now famous term "nuclear winter" to the world. Eventually, skeptical atmospheric scientists argued that Sagan's models ignored a variety of factors, including how dust reaches the highest levels of the atmosphere and how it can be dissipated by rainfall. Seven years later, in 1990, Sagan and his co-authors admitted they were wrong. Nevertheless, the world's media reporters, and hence the population, had already accepted his words as truthful because he was a celebrity more than because he was a scientist. Unfortunately, there was never the same "hoopla" over the retraction of his original article, and people today still think "nuclear winter" is a reality.

Remember the "very cold fusion" experiment reported in 1989 by Pons and Fleischmann at the University of Utah. They claimed to have duplicated nuclear fusion by squeezing the nuclei of deuterium atoms so closely together with those of a palladium cathode that they fused, releasing energy. However, as with all improbable or voodoo research, the experiment could never be repeated by anyone else. The print and visual media excitedly reported this, and the "hoopla" lasted for quite some time.

Another example of the lack of discernment involves the fact that for cancer-inducing agents to work, they have to break chemical bonds in DNA. It is well known that a bond can be broken by the ultraviolet wavelength. However, it is also known that any wavelength longer than ultraviolet cannot break a bond. Visible light wavelengths cannot cause cancer. Infrared light is longer, radio waves longer still, and power lines are still incredibly longer. They measure in miles. Knowing this, why then did the news media treat the issues with such dramatic coverage? And too, why did the federal government spend an estimated $25 billion to "discover" that power lines do not do anything more than deliver power?

There is another contributing element to the paradox. And it might be even more critical inasmuch as it is more passive in nature and becomes apparent only infrequently, but dramatically. The adage that university faculty need to "publish or perish" continues to blindly contribute to the problem as does the endless pressures to be successful in the discipline of grantsmanship.

Take, for example, the former Harvard researcher John Darsee. In 1981, he was found to be faking data in a heart study. Eventually, investigators at the National Institutes of Health discovered that data for most of his 100 publications had been fabricated. Take the cardiac specialist, Robert Slutsky, from the University of California San Diego School of Medicine. He resigned abruptly in 1985 after colleagues began to question the validity of his data and how he was able to turn out a new research article every 10 days.

There are many cases of voodoo science. Let us look at a very popular item in the news these last twenty years. Pamela Anderson had them taken out, as did Jenny Jones, and thousands of women across the country. They need not have bothered according to a panel of medical experts. Never mind that the lawsuit over breast implants bankrupted Dow Corning. The medical panel reported in 1998 that there is no greater incidence of immune-system abnormalities among women with breast implants that there is in the general population. Science did not fail, but the legal profession failed to understand science and will never admit that they do not understand science.

Stories like these will haunt research science for decades to come, and if the current state of affairs continues, they will continue during the next several decades. If you are interested in further reading, there are some interesting publications that document questionable research: *Annals of Improbable Research* (Editor: Marc Abrahams) and *Voodoo Research* (Robert Park).

The fallout of all these events has been the erosion of credibility, trust, and respect of research scientists, and the research process itself. As a result, it has been my observation that decision makers at all levels, whether appointed or elected, are today overly cautious regarding research and research scientists. This dilemma is in part due to a lack of initiative by researchers to educate decision makers in a manner that will bolster their confidence in and improve their scientific literacy and proficiency.

Decision makers need to be educated in the basics. For instance, what is and how does research work? Is there a scientific method or is research a process characterized by diligent, nearly myopic hard work that in the end has a goodly amount of creative chance with an Irish twist?

Decision makers who are associated with and deal with water resources need to know the meaning of risk. They need to understand that the regulatory world deals with hypothetical risks that are modeled projections and that often go well beyond what has been observed. Sometimes these models are fairly credible and sometimes they are not. For example, human risk based on laboratory animals exposed to very high doses are not a good model for humans that might be exposed to only a small fraction of that dose.

In the last thirty-five years, science, scientists, and researchers have lost significant credibility in the eyes of the public. As a result, research has been perceived by the public and decision makers as less than critical to the future of this nation. There remains in Congress the lingering attitude that research is a luxury the nation can ill afford. During the last decade less than two percent of the U.S. gross domestic product was devoted to research while comparative figures in Germany and even Japan remain above two percent.

I would therefore like to propose the possibility of developing a set of principles that researchers can adopt that would assist appointed and elected decision makers in the process of developing sound public policy. It goes without saying that environmentally related decisions should be based on sound science and technology. The question arises, however, as to how to ensure soundness. This then leads to the question: How do scientists and researchers improve the trust, confidence, credibility, and respect (TCCR) factors desired of them by decision makers? This question needs to be addressed on a continuum. Nevertheless, it appears that there is a set of principles that can be considered.

The knowledge and personalities of scientists and researchers are their principal assets. How these are perceived by decision makers are important and will lead to understanding how to begin the process of strengthening TCCR.

Scientists must act ethically. The products of their research provide the major source of information on complex and potentially significant environmental issues.

Scientists must communicate that research has limits and that its principles and processes are not perfect.

Scientists must take into consideration the complexities of issues far beyond their individual disciplines and be accepting of approaches that incorporate economics, law, politics, and public policy and other interests.

Scientists should assist decision makers understand the hypothetical basis of research and the role it plays in modeling projections of risk.

Scientists should communicate the integrity of research and researchers and that the decision-making process should not discount science for the purpose of expediency.

Scientists should assist decision makers and the general public in terms that are comprehensible. Good science cannot be left out of policy making. It will only prompt catastrophe.

Scientists should be willing to work with the media and encourage them to improve their understanding of

science. This does not mean compromising their integrity, but it does mean to assist reporters in comprehending the finer points of research and the need for honesty and to wean them away from the need to make the facts fit the story.

The current national science and technology component of the federal budget is spiraling down as a charred, smoldering skeleton of what it once was. Much of our national model for research rests in a traditional definition of science and technology. Today, as we are all aware, there is a blur between basic and applied research and technology. Applied technology drives basic science every bit as much basic research drives the applied engine. As an example, finding gene markers is basic science but building the machine to find the marker is termed technology. This fundamental model needs to be thoroughly transmitted to decision makers at all levels of our society.

The challenge to the two organizations sponsoring this conference is to ascertain their willingness to take a leadership role in championing the research enterprise and to do what is necessary to encourage leaders to become literate in the areas encompassed within water resources development and management. Some one has to take this position to halt the further erosion of the nation's intellectual capital.

Does the paradox exist? Yes, it remains today and will be with us for many years to come unless the research community at large can exert its leadership and work with the variety of decision makers at the local, state, and federal levels to create good public policy that is based on the best available scientific information and data. The research community will have to work at recapturing the minds of the American public by displacing the pseudo science of the past decades and replacing it with an integrated approach to assist decision makers to create a sustainable balance between society, the economy, and what we now know as a complex environment.

An interesting characteristic of the paradox is that it offers an opportunity to develop a framework for supporting decision making at all levels of government. Such a decision-support framework can offer a crosscutting integrated information base leading to an entirely new model for resources management that would take into consideration all the tools available today, including global networks.

The paradox is present; let us take advantage of it.

AUTHOR

Mr. Ronald Linsky is currently the Executive Director of the National Water Research Institute (NWRI) based in Fountain Valley, California, USA. As the founding director, he has been responsible for creating and implementing the development plan that has produced one of the more notable research institutions in the United States devoted to the applied research of water. The NWRI is unique among research organizations in the United States in that its core research funding is from a private source, the Joan Irvine Smith & Athalie Richardson Clarke Foundation. However, by designing and implementing a strategy of joint venture partnerships, the Institute has been successful in significantly increasing its annual core funding. In the last ten years, NWRI has invested over $14 million, which was matched with $16 million from its partners in more than 120 research projects through out the United States.

In his capacity as Executive Director, Mr. Linsky has been a nationally recognized advocate of integrated resources management strategies by incorporating water reuse, desalting, conservation, and efficiency components. His visionary skills served him well when in 1994-96 he was the principal consultant to the Sultanate of Oman for the purpose of developing the institutional framework that established the Middle East Desalination Research Center. Mr. Linsky has developed the concept of "the value of water" that is being incorporated into water reuse management strategies throughout the United States. He recently completed an economic valuation of water review for the Orange County Water District/Orange County Sanitation District joint Groundwater Replenishment System project. This project will treat over 75 mgd of secondary-treated effluent from a wastewater treatment plant by using reverse osmosis, micro-filtration, and ultraviolet light to create a very high-quality water product for the purpose of recharging the groundwater basin.

Because half of the world's 6 billion people live in urban centers bordering the shorelines of oceans, rivers, lakes, or estuaries, NWRI, under his leadership, has adopted water in the urban environments as the over arching theme for its 2002-2007 research program. The issues are complex and little understood, and will become even more critical in anticipation of an additional 2 billion people estimated to move into urbsn environments by the year 2020. His vision that water reuse, desalination, conservation, and efficiencies will contribute equally to resolving the pending urban water crisis is being adopted by agencies and organizations around the world as a reasonable strategy to reach a sustainable and reliable water supply.

In 2001, Mr. Linsky was an invited speaker to the Fourth Water Conservation Workshop held at King Faud

University, Dhahran, Kingdom of Saudi Arabia. His presentation focused on the significant issues associated with future technological advances required for wastewater reuse as a component of water resources planning and development.

Prior to his current responsibilities, Mr. Linsky served as the Chief Technical Advisor of the United Nations Development Programme (UNDP), Office of Technical Cooperation for Development, and was assigned to the Institute of Marine Affairs in Trinidad-Tobago, West Indies.