

Appropriate Science: Evaluating Environmental Risks for a Sustainable World

David Kriebel, Joel Tickner and Cathy Crumbley

Lowell Center for Sustainable Production

University of Massachusetts - Lowell

David_Kriebel@uml.edu

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Abstract

The education of environmental and health professionals must keep pace with the increasingly complex, uncertain, and interconnected risks that they will be called on to characterize and address. There is a growing awareness of the limitations of mainstream science in the face of global threats, and a greater appreciation of the need to find ways to explicitly manage the uncertainties that complicate nearly every important environmental debate.

One example is the looming crisis of global warming, which has pushed to center stage a debate over the weight of evidence needed to act – a debate that has until recently been carried on in professional journals and conferences, but has not reached down into undergraduate education. The public has now been made aware of the potential necessities and risks of acting in the face of uncertainty. The greenhouse gas controversy has also taught other important lessons – about the interconnectedness of ecosystems and health and the necessity of studying planetary systems in all of their complexity.

The precautionary principle is another recent development that brings attention to the interface between the science and policy of environmental protection. The precautionary principle has generated considerable interest among environmental and community activists and many policy makers who see it as a way to engage in debates over the kind of evidence needed for action – debates that have been traditionally conducted in terms of highly technical rules over the best way to calculate “acceptable risks” and the like.

These and other developments lead us to propose that students in the environmental and health sciences can become more effective agents of change if they receive training in what we call “appropriate science”. By appropriate, we mean that the methods have been chosen to fit the nature and complexity of the problem, and the social and political constraints of the communities concerned. Within the bounds of traditional scientific methods, there are many tools and approaches, but too often a narrow set is used for reasons of disciplinary tradition, perceived “rigor” and other aspects of professional practice.

In this paper, we will argue that undergraduates should be taught environmental and health science through engagement with real world problems, and that they should develop an understanding of the science–policy interface alongside their introduction to the basic tools of the scientific method. This training should include exposure to a wide range of disciplines and methodologies – including both quantitative and qualitative tools, as well as attention to the ethical responsibilities towards those who will be affected by one’s professional actions.

Introduction

More than 30 years ago, the environmentalist Barry Commoner wrote about the fundamental need for “Education for Sustainable Development”, although he did not use those words, exactly (Commoner 1971). In his most important book, The Closing Circle, Commoner wrote:

...we can trace the origin of the environmental crisis through the following sequence. Environmental degradation largely results from the introduction of new industrial and agricultural production technologies. These technologies are ecologically faulty because they are designed to solve singular, separate problems and fail to take into account the inevitable “side-effects” that arise because, in nature, no part is isolated from the whole ecological fabric. In turn, the fragmented design of technology reflects its scientific foundation, for science is divided into disciplines that are largely governed by the notion that complex systems can be understood only if they are first broken into their separate component parts. This reductionist bias has also tended to shield basic science from a concern for real-life problems, such as environmental degradation.

Commoner placed scientific reductionism, and by extension, science education, squarely in the center of the web of forces that lead to environmental degradation. At the same time, he foresaw an alternative future in which science played an equally central role in a human society in balance with the ecosphere. Inspired by Commoner, and many other visionaries, we see interdisciplinary, real-world problem solving as the centerpiece of our vision of education for sustainable development.

In this article, we present an approach to the assessment of environmental and health problems and the design of their solutions that we call “appropriate science”. The name is, in part, inspired by the appropriate technology movement, which takes as its founding text Small is Beautiful: Economics as if People Mattered (1973) by E.F. Schumacher. The name is also a reaction against the increasing politicization of science for environmental and health policy. Unfortunately, more and more critics of one or another environmental policy are challenging the scientific basis of the controversy, and sometimes even attacking the individual scientists who are producing the scientific knowledge about the issue. In many recent debates over such issues as global warming, urban air pollution, the effects of lead on children, and the environmental impacts of drilling for oil in the Alaskan National Wildlife Refuge, one can see attempts by powerful economic forces to undermine environmental and public health protections by attacking the underlying science and the scientists who conduct it. These attacks have often challenged the scientific basis for environmental and health protections by labeling some or all of the evidence as “junk science”. But what these critics call junk science often appears to us to be precisely the anti-reductionist science that Commoner called for more than 30 years ago.

We will briefly outline why we think it is useful to talk about “appropriate science” for environmental health protection, and conclude by urging the application of this vision to training in environmental health. In our view, sustainable environmental health training

should focus on improving and protecting environmental integrity, economic vitality, and social cohesion as the most effective means of assuring human health. Our perspective on environmental health stands in contrast to more conventional approaches to public health that seek to improve health outcomes by focusing on individual behaviors or the quantification of specific causes and mechanisms of disease and injury. We will also emphasize social responsibility and ethics for scientists and practitioners.

Appropriate Technology and Appropriate Science

The modern environmental movement, heavily influenced by the writings of Rachel Carson, Barry Commoner and others, grew and branched throughout the 1970s. One offshoot was driven by the energy crisis, and the political struggles over nuclear and solar power. The Appropriate Technology (AT) movement's guiding mentor was the economist E.F. Schumacher, who said: "AT is technology with a human face." This can mean many things, but in current usage, is generally interpreted as technology designed so that the average person can understand, operate and maintain it effectively. But while this is often viewed as a preference for "low tech" over "high tech", the AT movement generally also argues that appropriateness implies the widest possible choice of solutions to meeting human needs, including both modern scientific discoveries and proven traditional approaches, combined to insure the smallest possible "ecologic footprint" for human activities. Most definitions also include a vision of technologies that support a decentralized society which encourages democratic decision-making. Technologies such as solar power are seen as potentially more democratic, because they need not be organized into large, centralized systems, as are modern electrical power generators (Commoner 1976, Winner 1986).

Like appropriate technology, we define appropriate science as research methods chosen to fit the task – for example evaluating complex environmental impacts of new or existing technologies. There are many tools and approaches that are scientifically acceptable, but too often a narrow set is used because of constraints having more to do with narrow framing of the problem, the technical training of the researchers, the priorities of funding agencies, and biases of journal editors than with the particular challenges of the problem under study or the groups who will use the results of the research. In the approach we propose, technical and political solutions are weighed side by side, quantitative and qualitative research methods are respected equally, and occupational and environmental health are viewed as an integrated whole.

Inappropriate Science

There are two broad areas of concern in the current application of science to the prevention of environmental degradation and human illness – concerns that have convinced of the importance of the approaches to environmental science and to science education presented in this paper. First, there is a growing awareness of the *politicization of science* and the corruption of its impartiality and objectivity. Second, Commoner's critique of *reductionism* and its role in perpetuating environmental degradation is even more urgent 30 years on, given the mounting evidence of planetary environmental and health crises.

The politicization of science

A recent federal report, prepared by the minority staff of the Government Reform Committee of the U.S. Congress, found numerous examples of how the Bush Administration has manipulated scientific research and traditional scientific review procedures (U.S. House of Representatives, 2003). The report found that these efforts tended to benefit the political objectives of the President and his supporters. Evidence was presented suggesting that the Bush Administration has manipulated the memberships of scientific review committees when the political perspectives of committee members were questioned, and has interfered with scientific research through blocking research funding and the publication of research results, when these appeared to reflect badly on economic interests that support the Administration. Perhaps the most notorious example was the Bush administration's attempt to slow action to reduce greenhouse gas emissions by arguing that the science was inadequate, and more research was needed.

Under the Bush administration, the federal government has dropped any appearance of impartiality in debates over environmental regulations. For example, the Environmental Protection Agency and the American Chemistry Council, the trade organization of the chemical industry, are jointly sponsoring a series of workshops aimed at achieving better use of scientific knowledge in policy decisions on key environmental issues in developing countries, such as water and sanitation and marine pollution (U.S. Dept. of State, 2003). In other words, the U.S. government is promoting the chemical industry's views about its own regulation in poor countries.

Industries as well, are increasingly active in influencing scientific research, through challenges to the scientific basis of health regulations, targeted funding of research to answer particular questions, and participation on research and decision-making panels. The influence of the regulated community (or its third party-funded think-tanks) on the environmental health research agenda and policy has been widely documented (Fagin 1996, Markowitz 2002, Krimsky 2003). This influence is used to raise uncertainty about the strength of evidence identifying environmental hazards as a strategic smokescreen to avoid regulation (Abraham 1994). The increasing influence of the regulated community in the scientific process means that uncertainties will continue to be used as the basis for postponing policies that could be more protective of health and the environment.

The politicization of science should be countered with a variety of strategies, many of them involving legal safeguards to protect the impartiality of funding, conduct, and publication of scientific research. It is also important, however, to include explicit discussions of professional ethics in science education. This is especially important in a field like environmental health, where the consequences of research findings may have immediate political and social impacts (Quinn 2001).

Reductionism and the Principles of Reaction and Precaution

The second area of concern for environmental health science is not about corruption, but rather about inherent limitations in standard research methods which may limit innovation and interdisciplinarity in science. Current scientific research is often focused narrowly on refining old hypotheses rather than investigating new ones, and is limited as

well by the disciplinary boundaries within which nearly all scientific research is conducted. At present, much of the federally funded environmental research is focused on better understanding of the risks from chemicals and other agents that are already known to be hazardous – lead, asbestos, ionizing radiation. There is also a tendency to focus on narrow, quantifiable aspects of problems, thus inadvertently excluding from consideration potential interactions among different components of the complex biologic systems of which humans are a part. The compartmentalization of scientific knowledge further impedes the ability of science to detect and investigate early warnings and develop options for preventing harm when far-reaching health and environmental risks are involved. Resolving important challenges like the quantification of life-long cumulative effects of hazardous exposure or the combined effects of simultaneous exposures to several chemicals at once will require entirely different approaches that break new ground, and almost certainly will require teams of investigators with very different kinds of training.

We believe that one “policy driver” that can counteract the tendency towards reductionism in science is the precautionary principle (Tickner 1999, Kriebel 2001a, Tickner 2003). The precautionary principle can stimulate the kinds of comprehensive, systems perspectives that are needed to identify risks to environmental health quickly, and to develop effective alternative technologies. Four central components of the principle are: 1) taking preventive action in the face of uncertainty; 2) shifting the burden of proof to the proponents of an activity; 3) exploring a wide range of alternatives to possibly harmful actions; and 4) increasing public participation in decision-making. In contrast to precaution, many current public health and environmental policies are based on a principle of *reaction*. Government regulatory agencies are often put in the position of having to wait until sufficient evidence of harm is established beyond all reasonable doubt before they can act to prevent harm. A shift from reaction to precaution is entirely consistent with environmental and public health sciences, and can stimulate forward-looking rather than reactive approaches to how and what is studied.

The identification of safer alternatives and opportunities for prevention are central to the precautionary principle. Too frequently, policy makers ask the question: “How much risk does this activity pose and is it significant?” Or: “What level of risk is acceptable?” These questions, deeply ingrained in the regulatory approaches of many government agencies, tend to focus on the quantification of potential hazards rather than the prevention of pollution (Commoner 1990, Quinn 1998, Kriebel 2001b). They also often provoke a sharp debate about whether the risk has been characterized accurately. When researchers enter into this debate, they may inadvertently be ceding the most powerful position B questioning whether the hazardous substance or intervention is needed at all. A different, and potentially more precautionary way to think about uncertain risks is to begin from a different set of questions: “Is the proposed activity needed, and if so, how much contamination can be avoided while still achieving societal goals?” And: “are there alternatives to this activity which clearly avoid hazards?” For example, chlorinated solvents provide a cleaning function which can often be easily substituted with aqueous solutions. This shift in perspective requires a set of skills not always found in regulatory agencies B technology and product design, full cost accounting and other management

systems, and the broadest possible perspectives on the potential unintended consequences of policy choices.

Appropriate Scientific Methods

The complexity of environmental hazards, and the search for cleaner technologies should stimulate the integration of scientific knowledge from various disciplines and foster the establishment of new collaborations. Scientists, policy makers, and activists are assembling new types of collaboration and more expansive “frameworks” to address such hazards as endocrine disruption, global change, and other challenges to ecosystem health. Groups of scientists are beginning to view these problems through wide-angled lenses, gathering knowledge from various disciplines and speculative hypotheses (Krimsky 2000).

For example, a comprehensive analysis of different types of evidence concerning the effects of persistent pollutants on wildlife in the Great Lakes led Dr. Theo Colburn to hypothesize that a common mechanism of action may be causing the effects. Other researchers had also begun to detect signs of unexplained damage to wildlife. However, because of the fragmentation of scientific data, they had been unable to support their own suspicions or develop robust hypotheses using only evidence from their individual disciplines. An interdisciplinary conference provided the opportunity for many different fields to meet and share insights (Colburn 1992). They were then able to combine their evidence to support the hypothesis that persistent pollutants may be disrupting the hormonal systems of animals. The conference organizers summarized the outcomes: “So shocking was this revelation that no scientist could have expressed the idea using only the data from his or her discipline alone without losing the respect of his or her peers.”

Another example of the need for interdisciplinarity is the potential health and ecologic risks from global climate change. The scientific response has included important new syntheses, integrating the knowledge and contributions of different disciplines--medicine, toxicology, epidemiology, ecology, veterinary science, meteorology, and more --into a base of knowledge that can support the development of novel questions, hypotheses, and ideas as well as more efficient problem solving (Epstein 1998).

Entirely new scientific collaborations and disciplines, such as earth systems analysis, ecosystem health, and conservation medicine have been founded to address the need for interdisciplinary investigations. Conservation medicine is a new academic initiative linking human and animal health with ecosystem health and global change. The initiative arose from a growing understanding that human impacts on ecosystems are multiple and integrated, that ecosystems are becoming less resilient, and that professional preparation is needed to deal with these impacts. Conservation medicine involves establishment of interdisciplinary problem-solving teams, interdisciplinary education and multi-institutional research collaboration (Aguirre 2002).

Complexity and uncertainty, coupled with the establishment of new collaborations, have led to the development and increased use of innovative tools to more effectively characterize and prevent risks (Patz 2001, Martens 2002). These tools include:

integrated modeling and assessment in climate research (Chan 1999), health impact assessment (Steinemann 2000, Krieger 2003) and health and ecosystem indicators (US-Canada International Joint Commission 1995), Bayesian-influenced analysis (Neutra 2002), cumulative effects analysis (Fox 2002), community-based research (Sclove 1997), and green chemistry and design for the environment (Collins 2001). These tools are increasingly disseminated through peer-reviewed journals, government reports, and professional conferences. Such professional and governmental discussions lend critical credibility to the application, growth, and integration of these tools into research agendas and educational programs.

Several scientific disciplines have begun to recognize their limitations in addressing contemporary global risks. There has been a vigorous debate in epidemiology, for example, over the limits of an approach based on identifying individual health risk factors, to the detriment of population-level perspectives (Pearce 1996, Kriebel 2001c). Biologist David Ehrenfeld has noted that despite important efforts and advances in conservation biology and our understanding of ecological systems, the field has rarely been able to report measurable progress towards conservation goals (Seidler 2002). These disciplinary discussions on the need for new approaches and collaborations have resulted in the establishment of panels, working groups, and statements by professional organizations such as the International Society for Environmental Epidemiology, the American Public Health Association, the Society for Conservation Biology, the Society for Ecological Chemistry and Toxicology, and the Risk Assessment and Policy Association, among others. In addition, cross-disciplinary workshops addressing particular complex risks such as genetically modified organisms, biodiversity protection, endocrine disruption, and climate change are occurring on a more regular basis, funded by government agencies, private foundations, and non-governmental institutions.

Appropriateness means being conscious about selections and choices. It means making explicit the step of choosing methods, because the more conscious one is about choices, the more likely one is to see when new methods are needed. Traditional science often makes implicit choices about methods by selecting only from the limited set of methods that are “standard” within a particular discipline. This makes it difficult to notice when new methods are called for.

In sum, we define appropriate science as having some of these attributes:

- A more effective linkage between research on hazards and expanded research on primary prevention, safer technological options, and restoration;
- Increased use of interdisciplinary approaches to science and policy, including better integration of qualitative and quantitative data;
- Innovative research methods for analyzing the cumulative and interactive effects of various hazards to which ecosystems and people are exposed; for examining impacts on populations and systems; and for analyzing the impacts of hazards on vulnerable sub-populations and disproportionately affected communities
- Systems for continuous monitoring and surveillance to avoid unintended consequences of actions, and to identify early warnings of risks; and

- More comprehensive techniques for analyzing and communicating potential hazards and uncertainties (identifying what is known, not known, and can be known) (Tickner 2002).

Appropriate Training

Science education has a fundamental role to play in the changes we are advocating. But, at the same time, universities are among the most difficult institutions to redirect towards innovations in research and learning (Brown 2000). Universities have been slow to establish interdisciplinary environmental health programs and to update curricula to respond to the complexity of environmental risks. This is due in part to the dependence of academic centers on outside funding that directs the research (and hence educational) priorities. It is also true that many academic reward systems provide little incentive for innovation. To achieve tenure, professors are expected to have a strong publishing record in one field, which encourages focusing on well-established methods rather than experimenting with new approaches. Academics also tend to avoid “rocking the boat” by undertaking research projects, making statements, or engaging in collaborations that might draw unwanted scrutiny from colleagues or government policy makers.

The lack of innovation in new scientific approaches in education also has to do with an evolving view of the university as a “service” provider, with students as clients (Brown 2001). Under this view, universities provide students with “marketable” skills, which reinforces a focus on traditional scientific methods to the detriment of new tools and collaborations. For example, for more than a decade, epidemiologists have been discussing and criticizing certain tendencies in the field which favor the study of individual “lifestyle” risk factors over social determinants of health (Pearce 1996, Krieger 1999). Yet in a review of 25 epidemiology texts, Bhopal (1999) found that the majority taught the same old methods, and few discussed population-level approaches or the role of epidemiology in public health policy.

Further, despite some academic calls for educating students about the implications of their research and the products they create (Collins 2001), most schools do not train students in real world decision-making, nor in the social implications of their narrow field of expertise. Environmental health education should provide opportunities for students to understand the science-policy relationship, to be involved in decision-making processes and to interact with communities affected by environmental degradation.

Appropriate Science and Environmental Health at UMass Lowell

We propose to bring principles of appropriate science into the undergraduate curriculum at UMass Lowell in an Environmental Health Program. This program will encompass training in environment, health, economics, and systems of production. It would be interdisciplinary, field-based, and centered on developing problem solving skills. The goal would be to prepare students to be change agents, equipping them with the information, skills and intellectual power to push progress towards sustainability. Field-based engagement will cultivate awareness of the challenges and benefits of community participation and cultural pluralism.

Some key elements of the program include:

- Interdisciplinarity. A critical element of any environmental health education should be an interdisciplinary focus that combines natural and social sciences as well as the humanities.
- Professional ethics. The ethical challenges to the independence of environmental science should be addressed head on, and students should be encouraged to develop their own ethical perspectives. Formal instruction in the ethical guidelines of health and environment professionals should also be provided.
- Environmental and sustainability literacy on the Lowell campus. The Environmental Health curriculum should help increase environmental and sustainability literacy on campus, ensuring that considerations of environment and health are woven into the fabric of education and community outreach of all campus departments.
- Flexibility. Because environmental health is such a broad topic and there are many important routes to studying and solving environmental health problems, the program must ensure adequate flexibility for students to pursue areas of interest or concern. While students must have sufficient grounding in basic environmental health and general education requirements, they also must be able to develop learning concentrations that can be adapted to their particular interests and needs (for example in urban planning or the built environment, food safety, worker health, pesticides, etc.).
- Problem solving/research capacity. Environmental health encompasses a wide range of fields and issues so that we cannot expect students to have in-depth knowledge on all environmental health questions. The program should enhance the ability of students to examine, research, and solve complex environmental health problems. This requires a strong understanding of where to find the resources needed to solve a problem, solid skills in environmental writing, and a foundation in analytical thinking about environmental health problems.
- Community service focus. Because environmental problems affect health at the community level and solving them involves a complex array of science, community outreach, and politics, it is crucial that students have sufficient grounding in applied environmental health. Students will not understand the challenges of solving environmental health problems unless they spend time in communities, working for example with public health authorities, non-profit community groups, small businesses, and health care providers. Further, they will not understand the real life health impacts of a failure to protect the environment, until they begin to work with communities. Community service, project-centered learning, and interaction with those working at the forefront of environmental health problem solving must be an integral part of the program.
- Preparing students for good jobs in environmental and health-related fields, or graduate education. An undergraduate Environmental Health Program should adequately prepare students for good jobs in environmental health or other similar fields and/or graduate education in this field. There is a range of job

possibilities with an undergraduate degree in Environmental Health -- from town public health officers and sanitarians to consulting firms, government regulatory agencies, and industry health and safety positions. In addition, the program would offer a good foundation in research and problem solving skills – like any good liberal arts education, and so would prepare students for a wide range of possible jobs that require strong analytical, research, and writing skills. The program should also prepare students for high level masters and doctoral programs including Work Environment and RESD.

Conclusion

These are hardly new ideas that we propose. But their age does not detract from their relevance. On the contrary, three decades on from Barry Commoner's Closing Circle, and the rise of the modern environmental movement, the need for an interdisciplinary, solutions-based approach to science is no less urgent. Commoner wrote:

“...technology properly guided by appropriate scientific knowledge *can* be successful in the ecosystem, if its aims are directed toward the system as a whole rather than at some apparently accessible part.” And then a few sentences later: “Ecological survival does not mean the abandonment of technology. Rather, it requires that technology be derived from a scientific analysis that is appropriate to the natural world on which technology intrudes.”

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