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Toward Improved Environmental Decisions

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Abstract

A common feature of many of the current environmental issues is that the immediate impacts or risks, although considered to be small by many scientists, are uncertain and potentially wide spread and significant in the long term and thus of concern to potentially affected groups. The need to formulate decisions and commit major resources in the face of these uncertainties has led to the introduction of new environmental decision making frameworks that have as a central feature consideration of the broader environmental context and a greater involvement of the affected parties in the process. Various research activities and case studies are described which are targeted at aiding further development of the decision making frameworks into a more widely useable and effective approach.

Introduction

A fundamental change is occurring in the nature of the challenges confronting those making environmental management decisions. In the early days of the modern era of environmental concern (circa 1970s), management decisions involved identifying effective strategies to address serious and widely recognized problems with contaminated air and water. In the 1980s and 1990s, as information on potential environmental problems proliferated (including the extent of low-level contamination and statistical probability of effects in the exposed population), the concept of risk as a management tool was introduced to assist in setting priorities and establishing what were considered by scientists to be acceptable control levels.

The regulatory mechanisms established during those earlier periods, and in many cases subsequently refined, continue to be the cornerstones for attaining

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and maintaining many environmental objectives. However, with the improved understanding of potential exposure and effects from both new and previously regulated individual contaminants, there is growing recognition that the next stage of environmental protection will require a more holistic view that considers the aggregate environmental context. This more comprehensive decision-making perspective will make it necessary to consider the broader objectives of the affected populations, including health, economic, and sociocultural implications of environmental strategies. In addition, the issue of limitations of scientific knowledge in being able to give definitive answers on actual impacts under various conditions is increasingly becoming a concern in more recent environmental deliberations. The need to formulate decisions in the face of uncertainty with accompanying tradeoffs in use of resources leads to the need to involve the affected populations in formulating decisions and evaluating the outcome of those decisions.

Future Environmental Decisions

A number of existing or emerging environmental issues with unique features (as noted in Table 1) are making it difficult to reach consensus among the regulatory agencies, scientific community, and other interested and affected groups on appropriate strategies. It can also be anticipated that scientific discovery will continue to introduce new environmental issues that will challenge current decision and management approaches.

As indicated in Table 1, several common features of many current environmental issues are the impetus for new or revised environmental management approaches:

- Limited resources are forcing trade-offs
  e.g., use of scarce resources for costly cleanup vs. use for other societal needs
- Conflicting objectives
  e.g., more intensive cleanup vs. avoiding worker risks;
  use of natural resources for economic development vs. preservation of natural ecosystems
- Responsiveness to a range of public values and interests
  e.g., preserving natural habitats vs. economic development; conservative approach to development (precautionary principle)
- Uncertainty in actual risks
  e.g., because of uncertainties in sources, pathways (including transboundary dispersion), exposure levels, dose-response (availability of treatment or prevention), multiple stressors

Proposed Frameworks for Environmental Decisions

Frameworks for environmental decision-making that provide a more comprehensive and integrated approach have been proposed, most notably by the Commission on Risk Assessment and Risk Management as illustrated in Figure 1

Table 1 Decision Making Challenges for Current Environmental Issues

Environmental Issue	**Features that Challenge Decision-Making**
Global climate change	Uncertain impacts; need for international coordination; economic tradeoffs
Genetically modified organisms	Uncertain impacts; risk perceptions; impact on international trade
Nuclear materials and wastes	Risk of low level exposures; risk perceptions; long-lived hazards
Numerous sites with low-level contamination; closure on the cleanup	Future land use; worker vs. public risk; high cost of further cleanup
Urban environments; making our cities livable	Diverse values and interests; environmental justice
Trans-boundary air pollutants, especially persistent organic pollutants and fossil energy emissions	Uncertain impacts; need for international coordination; risk perceptions
"Safe" contaminant levels, e.g., for endocrine disrupters (dioxins), synergistic effects (mixtures, other environmental factors)	Uncertain low-level dose-response; risk perceptions
Natural ecosystems, biodiversity	Diverse values and interests; economic tradeoffs
Watersheds to provide adequate quality and quantity of water	Future demographics, economic development, land use; inter-regional competition
Alternative energy sources	Resource availability; economic tradeoffs; nuclear risk perceptions

Figure 1. Paradigm for Integrated Risk Management (Omen 1997)

(Omen 1997) and by the Science Advisory Board of the U.S. Environmental Protection Agency (EPA) (EPA 2000). A common feature of these frameworks is consideration of risks in the broader context of the real world involving other environmental conditions. The risk assessment can be structured to give useful comparisons to other elements within that broader context. Options for risk reduction should be as unconstrained as possible to allow a balancing with other risks, including health, ecological, economic, and sociocultural. The proposed frameworks also include an iterative mechanism in which the implemented decisions are periodically evaluated and adjustments made as appropriate. Direct involvement of affected parties is a fundamental component throughout the problem formulation, risk assessment, implementation, and subsequent evaluation.

Further research and development in several areas are required to achieve more effective integrated environmental decision making within the proposed frameworks. Tools must be further developed, for example, for the following:

- Performing aggregate, cumulative risk assessment, including for mixtures;
- Conducting valuations of ecosystems and evaluations of sustainability;
- Balancing short-term economic impacts with long-term health and ecosystem risks;
- Eliciting and clarifying public values and interests and constructing environmental objectives consistent with a diversity of values and interests;
- Structuring innovative management approaches within current regulatory, economic, and sociocultural constraints; and
- Monitoring performance (short and long term) and updating management approaches based on results.

Case Studies of Decision-Making Framework Components

The approaches to environmental decisions discussed in the previous sections are general frameworks and currently not intended to be detailed application guidelines. Given the limited experience with the approaches, the diversity of possible applications and unique contexts prohibit such prescriptive guidance, at least for now. In addition to the need for further development of tools, it will be useful to document experience with both the overall and individual components of frameworks in order to identify strengths and areas needing further development. The following selected examples of ongoing activities and case studies are intended to serve as aids to future developments and applications.

Integrated cumulative risk assessments, including risk of mixtures. The EPA has recognized the need to consider "a broader scope that integrates multiple sources, effects, pathways, stressors, and populations for cumulative risk analyses in all cases for which relevant data are available" (EPA 1997).

A holistic process is emerging for considering risks across disciplines and over space and time. Some of the conceptual issues associated with integrating risk and impact assessments for large contaminated sites are illustrated by the application to complex U.S. Department of Energy (DOE) sites being cleaned up

under the Department's environmental management program. (MacDonell 1999, MacDonell and Habegger 2000) The integrated cumulative approach mandates considering the effect of multiple stressors, beyond the single chemical approach; the overall health of the ecosystem, not just the effect of contaminants on individual species; the overall quality of life, not just primary and secondary effects of contamination on the health of an individual or group; and overall regional economic robustness, not just effects of contamination on individual sectors. To develop this integrated view, it is important to receive input on values from the entire community, not just from those who could be directly affected by individual contaminant sources.

Integrated assessment of ecosystem risks. Considering risk to ecosystems has become generally accepted as a key component of environmental decision-making, and the EPA has issued guidelines for conducting the necessary assessments (EPA 1998). However, the guidelines require considerable expertise in their application. A reviewer of the earlier 1992 version of the guidelines commented that "the major limitations related to the paradigm [on ecosystem risk] regard knowing how and when to use it" (Menzie-Cura 1996). Various agencies have been active in adapting the ecological risk assessment guidelines to their specific needs. (See, for example, the draft Navy guidance at http://web.ead.anl.gov/ecorisk).

Among the completed applications that are available as case studies is the ecological risk assessment to support cleanup activities at the U.S. Army Aberdeen Proving Ground, Maryland (Hlohowskyj et al. 2000). This risk assessment used field, laboratory, and modeling approaches to aid in (1) identifying areas contaminated at levels that represent an unacceptable risk to biota, (2) developing cleanup goals, and (3) selecting remedial alternatives for the site.

Multimedia exposure modeling. Past modeling efforts have not consistently estimated exposure of pollutants via multiple pathways. In response to this concern, the EPA Office of Air and Radiation is developing the Total Risk Integrated Methodology (TRIM), a multimedia, multi-pathway air pollutant modeling system primarily intended to support the Agency's regulatory decision-making for air pollutants (EPA 1999). The TRIM is designed to provide a scientifically defensible, user-friendly, and flexible framework for assessing both human health and ecological risks from exposure to air toxics or criteria pollutants. For the DOE cleanup sites, the RESRAD suite of deterministic codes have been used extensively as multiple pathway dose assessment tools for cleanup of sites contaminated with radioactive materials (see Figure. 2). The RESRAD code applies to the cleanup of soils, and the RESRAD-BUILD code applies to the cleanup of buildings and structures. The RESRAD and RESRAD-BUILD codes have recently been enhanced to provide a probabilistic analysis of dose related to uncertain input parameters (Yu et al. 2000). The codes are consistent with the current Nuclear Regulatory Commission guidance being developed for both deterministic and probabilistic dose modeling.

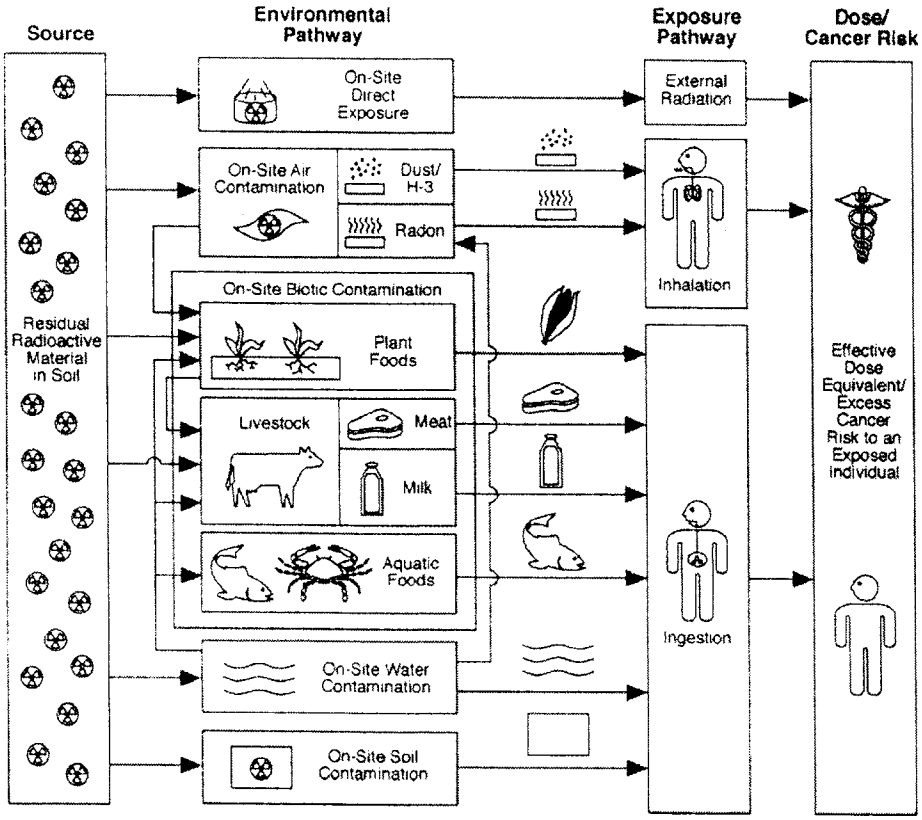

Figure 2 Graphical Representation of Pathways Considered in RESRAD

Stakeholder interaction and use of modern communication tools. A common feature of current approaches to environmental decision-making is the involvement of potentially affected parties so that "differing technical assessments, public values, knowledge, and perceptions are considered" (Omenn 1997). Three distinct levels of involvement are (1) decision makers providing to will form the basis for the affected parties information that was the basis for decisions; (2) decision makers obtaining input from affected parties prior to making the decision; and (3) agencies involving affected parties throughout the data collection, analysis, decision making processes, and during subsequent evaluation of results of implementation.

Extensive information can be provided to affected parties through printed documents, news releases, web sites, and compact discs. Frequently the problem is overloading the affected parties with more information (in particular technical information) than can be usefully processed. Some agencies are offering symposia or training programs to assist stakeholders in understanding issues.

The second level of involvement, obtaining input from affected parties before making the decision, is a familiar feature of decision-making through the National Environmental Policy Act (NEPA) process. Software enabling use of the Internet to receive, process, and respond to comments online (Stull 2000) has allowed incorporation of extensive public involvement to be incorporated effectively and efficiently.

At the third level, involving affected parties throughout the decision-making and implementation process is potentially the most effective feature, but also presents the greatest challenge because it is outside the normal mode in which technical analysts operate. Recent efforts have placed on a more theoretical basis the process by which analytical results can be integrated into the deliberative process involving non-technical affected parties (Apostolakis and Pickett 1998).

A straightforward, but powerful, illustration of the potential of modern communication tools to obtain input on environmental concerns is the combined effort of the Museum of Science and Industry (MSI) in Chicago and the Argonne National Laboratory to involve young school children in collecting environmental data from their surroundings, and to provide them a means for sharing this data over the Internet with other students in the Chicago area. In the "Tales from the Underground" project, teachers can purchase kits to analyze soil samples for pH, nitrate, and phosphate. The kits include passwords that allow students or teachers to locate their samples on computer maps and upload their results to a master database.

Results for all of Chicago are viewable simply by selecting sampling locations from maps and requesting a data table. Although intended primarily as an educational tool, this concept of involving community residents in collecting data could be extended to other environmental parameters.

The full potential of two-way communication over the Internet for enabling participation by parties affected by environmental decisions is still developing. Questions remain, for example, on the ability of the Internet to provide unbiased sampling of values, interests, and goals at the community, regional, or national level that would help drive the decisions.

Alternative environmental regulatory prototypes. A critical component of the recommended approaches to integrated environmental decision-making is the consideration of a wider set of options for risk management that take into account other factors such as technical feasibility, aggregate risk reduction, and economic consequences.

As an example, a recent study supported by a grant from the EPA-administered Environmental Technology Initiative evaluated two alternative future environmental regulatory approaches for today's petroleum refineries (Elcock et al. 2000). One alternative was goal-based, in which release limits are negotiated; the other was risk-based, in which estimated risk is the basis for setting or trading emissions. Both alternatives were designed to avoid current rigid approaches that limit consideration of site specifics, multimedia impacts, new technology potential, and flexibility to accommodate changing operational characteristics.

Summary

New approaches are required to formulate decisions for the next generation of environmental concerns. Comprehensive, integrated decision-making frameworks have been proposed, but essential tools require further development.

Among the primary needs are approaches for assessing aggregate, cumulative risks and a broad-based approach for eliciting and clarifying public values and establishing goals based on those values.

Acknowledgements

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References

Apostolakis, G.E., S.E. Pickett (1998): Deliberation: Integrating Analytical Results in Environmental Decisions Involving Multiple Stakeholders, *Risk Analysis* 18(5): 621-634.

Elcock, D., J. Gasper, D. O. Moses, D. Emerson, R. Arquero (2000): Alternative future environmental regulatory approaches for petroleum refineries, Environmental Science & Policy 3(2000) 219-229.

Hlohowskyj, I., J. Hayse, R. Kuperman, R. VanLonkhuyzen, (2000): Remedial Investigation Report for J-Field, Aberdeen Proving Ground, Maryland, Volume 3: Ecological Risk Assessment, U.S. Army, OP-SEC Control No. 2686-A-3.

MacDonell, M., Project Lead (1999): Risk/Impact Technical Report for the Hanford Groundwater/ Vadose Zone Integration Project, prepared by Argonne National Laboratory for the DOE Center for Risk Excellence and DOE Richland Operations Office, July 27.

MacDonell, M., L. Habegger (2000): Integrated Risk and Impact Assessments for Complex Contaminated Sites, Environ. Sci. & Pollut. Res., Special Issue 2 (2000) 13-20.

Menzie-Cura & Associates, Inc. (1996): An Assessment of the Risk Assessment Paradigm for Ecological Risk Assessment, prepared for Commission on Risk Assessment and Risk Management.

Omenn, G.S., Chair (1997): Framework for Environmental Health Risk Management, Final Report, Presidential/Congressional Commission on Risk Assessment and Risk Management, Washington, D.C.

Stull, E. (2000): Comment Response Management System (CRMS), Private communication.

U.S. Environmental Protection Agency (1997): Guidance on Cumulative Risk Assessment, Part 1: Planning and Scoping. July 3.

U.S. Environmental Protection Agency (1998): Guidelines for Ecological Risk Assessment, EPA/630/R-99-002.

U.S. Environmental Protection Agency (1999): Total Risk Integrated Methodology Status Report, EPA-453/R-99-01, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

U.S. Environmental Protection Agency (2000): Toward Integrated Environmental Decision-Making, EPA-SAB-EC-00-011, Science Advisory Board, Washington DC, August 2000.

Yu, C., D. LePoire, E. Gnanapragasam, J. Arnish, S. Kamboj, B.M. Biwer, J.-J. Cheng, A. Zielen, S. Y. Chen (2000): Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes, Argonne National Laboratory, ANL/EAD/TM-98.