

HAZARD AND RISK ASSESSMENT, AND RISK MANAGEMENT

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Contents

1. Overview of Assessment and Management of Hazard and Risk
 - 1.1. Ecological Risk Assessment
 - 1.2. Hazard and Ecological Risk Assessment
 - 1.3. Risk Management
 - 1.4. Organizational Structure
2. Scientific Knowledge Needed to Assess Ecological Risks
 - 2.1. Complexity of Ecological Risk Assessment
 - 2.2. Conceptual Models
 - 2.3. Framework for Ecological Assessment
 - 2.4. Retrospective Assessment
 - 2.5. Predictive Assessment
 - 2.6. Construction of Scientific Database
 - 2.7. Stressors
 - 2.8. Media
 - 2.9. Time Considerations
 - 2.10. Spatial Features
 - 2.11. Biological and Ecological Levels
 - 2.12. Socioeconomic Characteristics
 - 2.13. Uncertainties and Constraints
3. Hazardous Wastes and Other Substances Causing Risk Concerns
 - 3.1. Hazardous Wastes
 - 3.2. Industrial and Mining Wastes
 - 3.3. Air Pollutants
 - 3.4. Radioactive Waste
 - 3.5. Urban Solid Waste
 - 3.6. Sewage

- 3.7. Agriculture
- 3.8. Introduction of Non-Indigenous Species
- 3.9. Genetically Modified Organisms
- 4. Criteria for Estimating Ecological Risk
 - 4.1. Multidimensional Nature for Criterion Setting
 - 4.2. Weak versus Strong Sustainability Criterion
 - 4.3. Critical Levels
 - 4.4. Endpoint Criteria
 - 4.5. Combination of Criteria
 - 4.6. Tiered Risk Assessment
 - 4.7. Accident Risk Assessment
 - 4.8. Use of Hazards Indexation System
- 5. Environmental Protection and Risk Management: Principles and Policy
 - 5.1. Sustainability Principles
 - 5.2. Efficiency Principles
 - 5.3. Equity Principles
 - 5.4. Institutional Instruments
 - 5.5. Integrated Environmental and Risk Management
- Glossary
- Bibliography
- Biographical sketches

Summary

In the context of risk assessment and management, the term environment has often been intended by default to imply “for humans.” It may be necessary, however, to address the hazards and ecological risk assessment separately from human health risk for a better understanding of the problem and management of ecological systems. This discussion is therefore intended to address ecological risk assessment and management.

The scope of ecological risk assessment has been expanded from the traditional chemical and accident assessment to the inclusion of the potential harm from artificial introduction of species, both natural and genetically modified, into an ecosystem. Thus major categories of ecological hazards include chemical, physical, biological, and/or their combinations. Ecological entities can be more complex with respect to system structure and functions, although the methodologies are largely transplanted from human health risk assessment. Ecological risk assessment processes would involve problem formulation, characterization of exposure and ecological effects, and risk characterization. The assessment can be made retrospective or predicative, depending on the risks involved and management requirements. In either case, scientific knowledge is essential on stressors, environmental media, time and spatial features, and biological and socioeconomic characteristics. There is a diversity of criteria for ecological assessment but the essence is to ensure the “safety” of ecological entities

under assessment.

Risk assessment and risk management are two distinct but complementary parts of the regulatory decision-making process. It is shown that, for the management of ecological risks, a set of principles has to be employed. To ensure environmental sustainability, ecological principles must be observed; to make environmental protection and risk management effective and efficient, economic principles should play an important role. As all the principles must be understood and implemented by human society, equity concerns must also be addressed. For better ecological risk management, these principles are further substantiated with managerial elements for policy making.

This discussion will focus on ecological risk assessment and management although it is related to and largely derived from methodologies from human health impact assessment. For a clear understanding of the scope of the discussion, this introductory section will provide an overall definition of the problems related to hazard and ecological risk assessment and management, and outline the structural framework.

1. Overview of Assessment and Management of Hazard and Risk

1.2. Ecological Risk Assessment

The concern over environmental problems originated from the hazardous impact of pollutants and their risks to human health. As pollutants cause harm to human health, and damage the environment in the first place, their hazardous nature in terms of the ecological system was later recognized and paid attention to. In the context of risk assessment and management, however, the term environment has often been intended by default to imply “for humans.” So environmental risk assessment is taken to mean assessment of risks to human health from exposure to hazards in the environment at large. Against this background, ecological risk assessment is used to refer to the assessment of risks to non-human communities and populations. This artificial distinction, between human and other organisms and between the routes of exposure to which both are subject, can be significant in the management of the problem. But the conventional treatment is to consider ecological risk assessment—for ecological systems—a subset of environmental risk assessment. In fact, methodologies and processes for ecological risk assessment are either copied, or modified, from those for health risk assessment.

However, ecological risk assessment can be more challenging than assessment of impacts on human health, partly because more work has been done on the human side and perhaps even more so because ecological systems are more complex and less understood. It may be necessary to address the hazards and ecological risk assessment separately from human health risk for a better understanding of the problem and management of ecological systems. Two reasons are given. One is that ecological

elements have become an increasingly important direct component of human welfare and the other is because hazards to ecological systems are also a risk to human health. In addition, the issue of ecological risks has been of increasing importance in the policy arena. In this connection, the discussion here is oriented towards hazards and ecological risk assessment.

1.2. Hazard and Ecological Risk Assessment

Besides natural hazards and risks, perhaps all human activities may have potential to cause harm to ecological systems. Some may be potentially more harmful than others and need to be assessed and brought under management given the constraints that human society has to face. Before assessment and management action can take place, it is useful to clarify the meanings of hazard and risk.

Hazard often refers to potential to cause harm or an adverse event. It is observable and factual. Therefore, no uncertainty is involved in its description under knowledge as given. The term risk is used in everyday language to mean “chance of disaster.” In the context of risk assessment, the definition has to be more specific. The “most commonly accepted” definition is the combination of probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. Every risk involves a combination of two factors: (1) probability of an undesirable occurrence and (2) the severity of that occurrence. Take toxic chemicals as an example. They may be hazardous to wildlife. Heavy metals are poisonous to animals. The risk of the heavy metal in question adversely affecting the life of an animal will be determined by the likelihood that, in specific circumstances, it will cause a specific degree of harm. If the animal is going to intake the heavy metal only after it has been heavily diluted, the risk of being killed or poisoned will be minimal but the hazardous property of the heavy metal remains unchanged. This illustrates a fundamental concept, underpinning the theory and practice of ecological risk assessment: the nature of the hazard will not be changed but exposure dictates whether harm will actually occur.

In the context of ecosystem management, the loss of wildlife habitat is a hazard or threat to the protection of biodiversity and/or endangered species. Earlier literature on hazard assessment and eco-toxicological analysis concentrates on hazardous chemicals. However, chemical, physical and biological hazards, and the combination of all these three types of hazards can cause harm to ecosystems as they are likely to lead to the reduction in biodiversity and/or species extinction, depending on the scale of the hazard and efforts devoted to risk management. Therefore, an ecological risk is often expressed as a statistic (e.g. the probability of species extinction or ecological irreversibility, due to exposure to specific situations or conditions such as deforestation and high levels of pollutant concentration in the environmental media).

Describing hazards and carrying out the tests are often referred to as, respectively,

hazard identification and hazard assessment. In considering ecological harm from human activities, risk assessors search for effects against standard species that are presumed to be ecologically relevant in dose-response tests. Therefore, risk assessment is the procedure in which the risks imposed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively. In the life cycle of a chemical, for instance, risks can arise during manufacture, distribution, use, or the disposal process. Risk assessment of the chemical involves the identification of the inherent hazards at every stage and an estimation of the risks posed by these hazards. Risk is estimated by incorporating a measure of the likelihood of the hazard actually causing harm in terms of the consequences to the environment. The scope of ecological risk assessment has been expanded from the traditional chemical and accident assessment to the inclusion of the potential harm from artificial introduction of species into an ecosystem and that of genetically modified organisms (GMOs). Major categories of ecological risk assessment may include:

- Chemical risk assessments: attempt to estimate ecological consequences that might result from biological and ecological exposure to chemical substances (e.g. heavy metals, acid rain, or increase in carbon dioxide (CO₂) concentrations in the atmosphere).
- Accident risk assessments: evaluate the risks of an accident (e.g. fire, explosion, leak, and spill) occurring under certain specified or assumed activities or conditions.
- Ecological risk of introducing exotic species: assess the ecological effects of a new species, introduced on purpose or accidentally by humans, on indigenous species and ecosystems.
- Ecological risk due to the release of GMOs to the biosphere: consider the likelihood of the hazardous impact of GMOs on biological species and ecosystems.

Perhaps more important is the risk of direct physical damage by human activities, in particular, deforestation, overfishing, illegal hunting, and conversion of wetland into arable land. As these activities are straightforwardly adverse and have been treated in the policy arena, and may be partly covered in accident risk assessment, this category is normally not listed for complex ecological assessment in the existing literature. Consequently, the discussion will not focus on these physical damages although this does constitute an important area for further research.

1.3. Risk Management

Risk assessment can organize the scientific information needed to make regulatory decisions about specific substances, but it cannot make these decisions. Judgment is needed to integrate risk assessment with societal considerations (e.g. economic, political, technical feasibility, and common sense) (see Figure 1). This is the area of risk management. Risk assessment and risk management are two distinct but complementary

parts of the regulatory decision-making process.

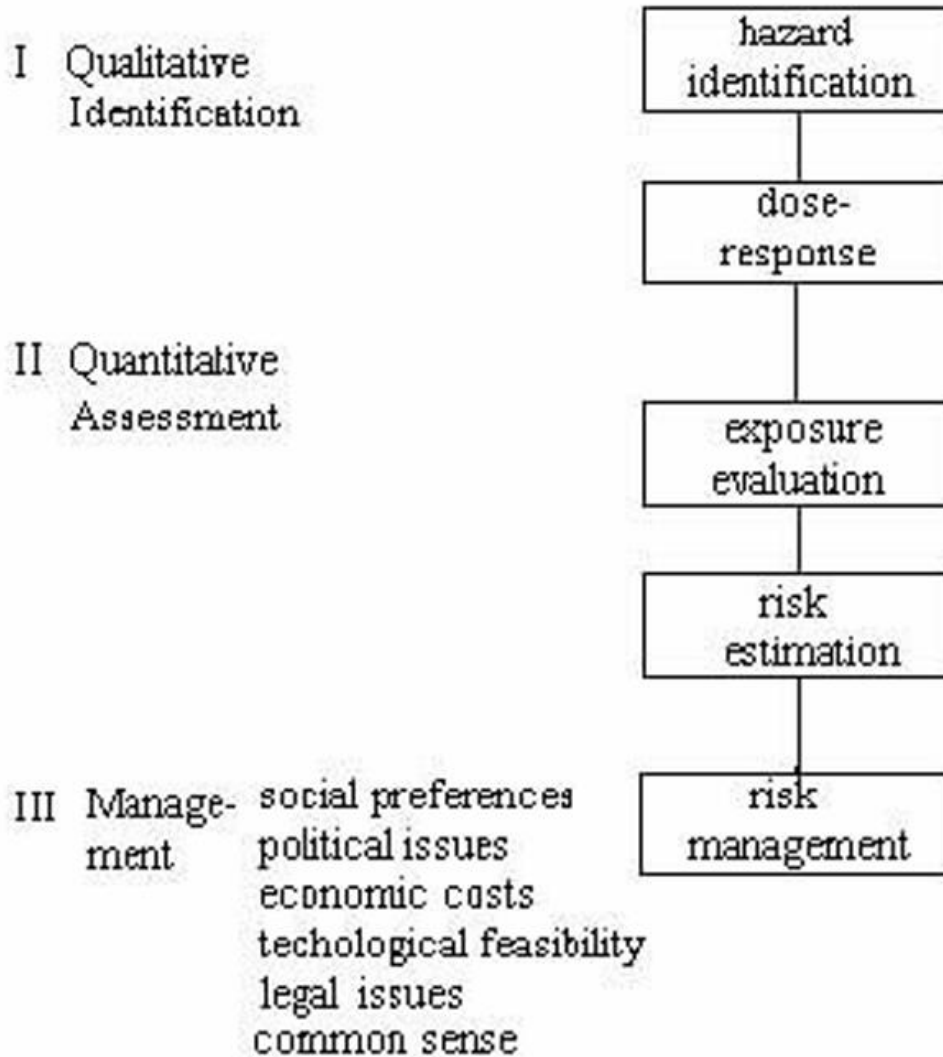


Figure 1. Risk assessment and management process

There are four types of analyses that have been used in risk management:

- Risk-benefit analysis: balances the economic benefits of a polluting activity against the associated risks to health and the environment.
- Cost-benefit analysis: weighs the cost of control, explicitly and directly, against the monetized benefits of control such as the avoidance of diseases and the attainment of social goods.
- Cost-effectiveness analysis: compares risk reduction per unit cost among several options for dealing with a risk.
- Risk-risk analysis: establishes the importance of an estimated risk. Such a study

considers the magnitude of an added risk relative to other acceptable risks such as occupational hazards or natural disasters.

The assessment of ecological hazards of an exposure is based upon eco-toxicological evaluation of the factor, which can involve the assessment of ecological effects of controlled exposure in a group of animals or plants, usually to relatively high levels of the factor. An assessment of the actual risk due to the presence of the hazard in the environment is based on the information concerning the population exposure to the factor and on the knowledge of the exposure-response relationship. The purpose of ecological risk assessment is ecological management. It provides decision makers and other stakeholders with the necessary information on the possible ecological impact, the alternative control measures, the likely socioeconomic implications, and necessary management policies as the scientific base for sound ecological management. Therefore, the assessment is an interactive, reiterative, and management oriented process (Figure 1).

1.4. Organizational Structure

Scientific knowledge is essential for the assessment of ecological cost. Ecosystems are complex and diverse in terms of their components, structure, and capacity to respond to hazards. The following section will be devoted to this important issue. This is followed by a description of the major types of hazardous wastes and other substances that cause risk concerns. Some materials may not be hazardous of themselves but may cause harm to some of the components of an ecosystem and thereby to the structure and function of the system. For instance, an exotic species does not contain any chemical ingredients that threaten plant life in the conventional risk sense. But it may colonize the habitat of indigenous species and cause harm to the ecosystem. Such organisms should also be regarded as hazardous to ecosystems although they do not have hazardous impacts on human health. There are many criteria for different purposes. For the estimation of ecological risk, certain specific conditions must also be identified. These criteria will be explored in *Section 4. Criteria for Estimating Ecological Risk*. All the analyses are intended to serve the purpose of sound ecological management. With basic knowledge on hazardous wastes and criteria for risk assessment, principles and policy issues are to be examined together with basic managerial elements in *Section 5. Environmental Protection and Risk Management: Principles and Policy*.

2. Scientific Knowledge Needed to Assess Ecological Risks

Ecological risk assessment can be easier than that for human health risk as much of the accumulated scientific knowledge base with respect to chemical hazards and methodologies may also be relevant to ecological risks. However, this may be only partially true considering the complexity of ecosystem structure and functions. Therefore the conceptual model must be tailored to the specific need for ecological

considerations. Furthermore, the scientific database must be much larger than that for health impact analysis as the latter can be undertaken with limited experimental/laboratory conditions. In addition to time and space scale, which may be beyond that for the test of human health risks, there is a large knowledge requirement for the dose-response relationship for individual organisms, populations, communities, and the whole ecosystem. As a result, uncertainties and constraints are unavoidable but they must be well understood and borne in mind in the assessment exercise.

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Biographical sketches

Yaping Du, born in 1960, Associate professor with the Institute of World Economics and Politics, the Chinese Academy of Social Sciences. Received a bachelor's degree in agriculture in Wuhan, China, in 1982 and worked as a researcher for the Economy and Environment Programme for Southeast Asia (based in Singapore) evaluating water quality improvement in China, Her major areas of interest include environmental and ecological management and development issues related to the environment.

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