THE PRECAUTIONARY PRINCIPLE IN SUSTAINABLE ENVIRONMENTAL MANAGEMENT

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Summary

The precautionary principle is increasingly being recognized as a central principle of sustainability. This article presents a history and rationale for the precautionary principle, and some steps for its implementation in sustainability policies. The principle has explicitly emerged in environmental decision making recently, with the realizations that (1) science is unable fully to address complex causes of environmental degradation, (2) government is responsible to protect citizens in the face of uncertain harm, and (3) values and judgment are an integral part of the decision-making process.

Precaution is much more than a risk management principle. It affects how science is conducted; how products, production processes, and activities are designed; how information is weighed in making a decision; and who is involved in the decision process. In this way, precaution guides our choices so that they are based on more holistic thinking, acknowledge what we know and do not know, and are respectful of human and ecosystem health and future generations. Precaution is about preventing harm, not progress. While human activities cannot be risk free, humans can do a much better job harnessing science and technology for sustainability.

1. Introduction

The enormous growth of novel technologies following World War II signaled the beginnings of a new industrial era, one of great prosperity, improved health, and new conveniences for society. However, the explosive growth in new technologies, industrial production, and globalization has also resulted in a large-scale experiment on ecosystem and human health, the full impacts of which are still unknown and may never be well understood. The precautionary principle was developed in the 1970s as a response to the limitations of early public policies that attempted to address the impacts of industrial production using the notion of assimilative capacity (i.e. that humans and the environment can tolerate a certain amount of contamination or disturbance, and that this amount can be calculated and controlled). Current attention to the precautionary principle arises from a growing understanding of the limits of science to predict complex environmental and health risks or provide clear-cut answers, and an understanding of the duty of government to protect its citizenry from harm. Contemporary global threats, such as climate change, species decline, genetically modified organisms, and endocrine-disrupting chemicals pose even greater challenges to science. As a result, the precautionary principle is increasingly being recognized as a central principle of sustainability. This article presents a history and rationale for the precautionary principle and some steps for its implementation in sustainability policies.

The precautionary principle has had a short but tumultuous history in environmental policy. On the one hand, its roots can be traced to familiar lessons from our grandmothers such as “look before you leap,” as well as hundreds of years of medical and public health practice. John Snow intuitively used the precautionary principle when he famously removed the handle of the Broad Street pump on the basis of an educated, informed judgment that it was the source of London’s cholera epidemic. Precaution was also inherent in many of the early environmental laws and government policies of the 1970s. However, it explicitly emerged in environmental decision making only recently, with the realizations that (1) science was unable fully to address complex causes of environmental degradation, (2) government was responsible to protect citizens in the face of uncertain harm, and (3) values and judgment are an integral part of the decision-making process.

2. Rationale for Precaution

Industrial development increased rapidly following World War II, with little regard for human health or the environment. Growth was synonymous with prosperity, and environmental damage seemed a small price to pay for the benefits of industrialization. Research and legislation developed in many countries during the late 1960s and early 1970s, however, acknowledged that there were substantial adverse impacts associated with unlimited growth. Scientists increasingly recognized that ecosystems, living organisms, and the impacts of various stressors on both were vastly more complex than they had previously thought. As zoologist Jane Lubchenco has noted, “Humans have unwittingly embarked upon a grand experiment with our planet. The outcome of this experiment is unknown but has profound implications for all of life on Earth.”

Since the mid 1970s, government agencies around the world have developed and employed numerous decision-making instruments to assess and control the environmental and public health effects associated with industrial activities such as synthetic chemical production, use, and releases and deforestation. In many countries, such instruments as cost-benefit analysis and risk assessment have been used to examine hazards and make decisions based primarily on level of risk. These instruments generate a specific quantification of potential impact, which is used to set exposure (or acceptable impact) standards. This approach is based on an assumption that impacts on complex systems can accurately be predicted through simplified models and that such systems have a certain “assimilative capacity.” It places an enormous burden on science to determine and detect “safe” levels.

While these instruments have been used successfully to control certain hazards, the limitations of the assimilative capacity approach have been demonstrated through its failures. The price of oversimplification and precision is error and limited comprehension. The more obvious failures—such as fisheries collapse, contamination of the Great Lakes and North Sea, childhood lead poisoning, and asbestos-related lung disease—are relatively easy to link back to their causes. The less obvious failures—increases in the incidence of developmental disorders and cancer, species extinction, and global climate change—are complex, have multiple causes, and are not so easily explained.

3. Inadequacies of Risk Assessment Methodologies for Supporting Sustainable Development

Conventional environmental decision-making methods suffer from several constraints on their ability to identify, anticipate, and prevent potential harm to human health and the environment. These constraints often delay decisions on potentially harmful activities or promote a false assumption of safety. Potentially irreversible harm can occur while resource-intensive research to determine causal links is carried out.

Toxicity testing for industrial chemicals provides an important example of the uncertainties involved and limitations of current approaches to environmental decision-making. As early as 1984, the U.S. National Academy of Sciences noted the overwhelming lack of data on the health effects of industrial chemicals. The Academy found that 78% of the chemicals in highest-volume commercial use did not have even “minimal” toxicity testing.

Recent studies by the Environmental Defense Fund (a U.S.-based NGO) and the U.S. Environmental Protection Agency have found that the situation has not improved some fourteen years later). For the almost 3,000 High Production Volume (HPV) chemicals, those over one million pounds in commerce, the studies noted the following: 93% lack some basic chemical screening data; 43% have no basic toxicity data; 51% of chemicals on the Toxic Release Inventory lack basic toxicity information; and a large percentage of available information is based only on acute toxicity.

Box 1. Example: Knowledge of chemical toxicity
(*Source*: National Research Council, *Toxicity Testing: Strategies to Determine Needs and Priorities* (Washington, D.C.: National Academy Press, 1984); Environmental Defense Fund, *Toxic Ignorance: The Continuing Absence of Basic Health Testing for Top-Selling Chemicals in the United States* (Washington, D.C.: Environmental Defense Fund, 1997); United States Environmental Protection Agency, *What Do We Really Know about the Safety of High Production Volume (HPV) Chemicals* (Washington, D.C.: USEPA, 1998).)

Limitations in scientific knowledge. The capacity to identify adverse health or environmental effects is limited by the present state of scientific knowledge. A lack of comprehensive knowledge about industrial development and its effects on ecosystem health makes it extremely difficult to even identify what to look for and where. Scientific knowledge is especially limited on the variability of ecological systems and the effects of pollution and other human activities. The question for decision makers is how science can establish an assimilative capacity—a predicable level of harm from which an ecosystem can recover—or a “safe” level of exposure when the exact effect, its magnitude, distribution, and interconnections are unknown.

Many activities and substances once thought benign, such as chlorofluorocarbons, have been shown to have severe environmental effects. Case studies and common-sense scientific observation often suggest causal links decades before those links are conclusively proven. For example, concerns about the health hazards of asbestos and benzene were identified as early as 1898 but preventive actions were not taken until almost a century later. Waiting for “convincing” evidence has often been costly in terms of human health, ecological damage, and the resources needed for remediation and restoration.

Need for statistically significant results. Regulatory programs often fail to consider fully “statistical power” in decision making. Statistical power describes in mathematical terms the probability that an experiment or monitoring program will actually detect an effect where one exists. Regulatory programs often demand demonstration of statistical significance in experimental and observational research. However, even though an effect is not statistically significant, it may be of public or ecosystem health significance.

Statistical power is directly influenced by sample variance (natural variability in the sample and measurement error) and magnitude of effect. Because ecological systems are complex in structure and function, they are subject to intrinsic variability and confounding from multiple stressors, pathways for effect, and causative agents.

Coupled with the difficulty in detecting small increases in risk, the insistence on statistical significance leads to research approaches that minimize the probability of incorrectly concluding that there is an effect when one does not exist—a “type I” error (e.g. a bias against accepting the validity of health effects when small populations are involved). This minimizes the likelihood that an agency would erroneously impose regulation. However, this focus on minimizing type I errors means increasing the chances of incurring “type II” errors, that is, failing to identify or act upon an adverse effect. There is an imbalance between these two types of error in most environmental studies. Conventionally, scientists must achieve 95% certainty that results are unlikely to be due to chance before they are considered statistically significant (a one in 20 chance of committing a type I error). The chance of committing a type II error, however, is conventionally allowed as high as one in five.

Low-level adverse effects. Understanding of low-level effects of multiple stressors on health is evolving slowly. For example, there is growing evidence that some synthetic chemicals may disrupt the hormone system at very low levels of exposure during sensitive periods in the development of organisms. The same chemicals may have little or no effects even at high exposures before or after these periods. Similarly, small changes in ecosystems may result in long-term effects.

These low-level adverse effects pose several difficulties. First, we have relatively little information about how exposure may affect developing organisms. Monitoring very low levels of exposure is technically challenging and subject to wide uncertainties. Controlling industrial emissions at very low concentrations is limited by current technologies. Finally, if adverse effects are being observed at very low levels of exposure, there is reason to believe that the same effects may occur at even lower but currently unmeasurable levels.

Cumulative, interactive, and global effects. Traditional decision-making strategies have focused on single-stressor, single-medium, localized effects, when in reality ecosystems are exposed to a wide variety of physical and chemical stressors exerting impacts far from the particular emission or activity. For example, certain groups of Inuit in Canada and Greenland have high levels of polychlorinated biphenyls in their body tissues, though they have never been directly exposed to them. Large-scale complex systems pose even greater uncertainty in defining and analyzing problems. Environmental science is only beginning to address the cumulative effects (at the local and global levels) of a wide range of physical and chemical stressors to which humans and ecosystems are subjected. For example, it is thought that small, relatively insignificant stressors may interact over time to result in catastrophic impacts, but it is very difficult to measure or monitor such interactions.

Sensitive sub-populations. Evidence and understanding is increasing of the disproportionate impacts of environmental degradation on specific populations and ecosystems. Certain social groups (organisms or ecosystems) may be at higher risk of adverse effects because of genetic disposition, disease status, developmental status, social status, and geographic location. For example, children (and other immature organisms) have a unique susceptibility to the effects of toxic substances due to their immature metabolic processes, rapid development, and exposure. Sensitive sub-populations and the high variability in responses to environmental insults within an exposed group are frequently overlooked in current environmental decision-making processes. Populations of organisms at the extreme margins of their species ranges may likewise receive disproportionately severe impacts from environmental degradation.

3.1. Uncertainty: The “Elephant in the Closet”

Uncertainty is an inevitable condition surrounding all environmental decision making. But because it complicates decision making, it is generally played down or ignored. Uncertainty is inevitable because humans operate in open, dynamic environments that are difficult to control. For example, variability among individuals or ecosystems generally cannot be reduced. Complex, unpredictable, and uncertain systems may produce consequences that are unpredictable, irreversible, and very costly. As a result, uncertainty pervades our attempts to understand the impacts of human activities on ecosystems and health for two reasons: (1) scientific tools are limited in their ability to identify, measure, and anticipate harm to human health and the environment and (2) we live in complex, dynamic, heterogeneous systems.

Environmental decision making can hardly ever be based purely on objective, conclusive science; such certainty is nearly impossible to achieve. Different types of uncertainty exist in characterizing hazards to health and the environment:

- *Parameter uncertainty*. This type of uncertainty refers to missing or ambiguous information about specific informational components of an analysis. Typically, parameter uncertainty can be reduced by acquiring more information. However, if such uncertainty is due to variability, this may not be the case.
- *Model uncertainty*. Models are theoretical constructs with the purpose of explaining or predicting events. Models of environmental systems at best show only a simplified and incomplete picture of reality. Model uncertainty refers to gaps in scientific theory or imprecision in the models used to bridge informational gaps, such as a dose-response model. Models can be improved only as knowledge improves.
- *Systemic or epistemic uncertainty*. This is uncertainty about the effects of cumulative or additive exposures and about interconnections that science cannot readily understand. This type of uncertainty increases as the size of the decision horizon and scope of analysis increase.

Two additional types of non-scientific forms of uncertainty exist: (1) *"smokescreen" uncertainty* where critics of preventive public policy measures create uncertainty by not studying or hiding potential impacts, or creating studies to increase the appearance of uncertainty; and (2) *politically induced uncertainty,* when government agencies may decide not to study a hazard, purposely limit the list of alternatives considered or the scope of analysis, downplay uncertainty in decisions, or hide uncertainty in quantitative models. A large determinant of ignorance and uncertainty may be the choice not to perform research in certain areas.

Uncertainty analysis deals only with known uncertainties. Decision makers have generally failed to consider more profound, unknown uncertainties—*indeterminacy and ignorance*—in making decisions that affect the environment and public health. The condition of indeterminacy—what cannot be known—reflects not only a lack of linkage between cause and effect, but also relationships between upstream action and downstream effects in open-ended systems with multiple influences. Ignorance is the state of not knowing what we do not know (e.g. not knowing which elements of a problem we are uncertain about). It, too, is intrinsic in the complexity of environmental problems and the limitations of analytic tools.

3.2. The Response to Uncertainty: Risk Assessment and Risk-Based Regulations

Since the mid 1970s, the regulatory and scientific response to environmental degradation and uncertainty in many countries has focused heavily on the development of quantitative assessment methods. During the 1970s, tools such as risk assessment and cost-benefit analysis were developed in the United States and elsewhere to assist decision makers in making complex decisions about industrial activities and their impacts. These methods presuppose the ability to characterize and quantify complex hazards and their probability of occurrence objectively and adequately. These predictions are then incorporated into decisions that are based on government-established levels of “reasonable” or “acceptable” risks, and often on economic feasibility. Risk assessment was originally developed for mechanical problems such as bridge construction, where the technical process and parameters are well defined and can be analyzed. By definition, “risk” indicates that probabilities are well understood. However, risk assessment has often taken on the role of predictor of extremely uncertain and highly variable events.

The risk-based system of decision making often requires a high level of certainty before taking action and is not generally oriented toward seeking solutions. It frequently places high confidence in the magic of numbers at the expense of judgment. Uncertainties tend to be underrepresented through quantitative point estimates. Under such a system, zero risk is an unachievable goal and health and ecosystem damage becomes inevitable; balancing and managing risks becomes the priority. Activities are generally considered harmless unless risk can be demonstrated with reasonable confidence. The burden to change the status quo falls on potential victims and not those who stand to gain from potentially harmful activities. This placing of the burden on potential victims in turn can reward ignorance about the impacts of potentially harmful substances and activities.

3.3. The Impacts of Uncertainty on Environmental Decision Making and Sustainable Management of Resources

Under current decision-making approaches, science is considered to be rational, value-neutral, and objective—an independent arbitrator. All this is implied in references to a “science-based” process. In the mid 1980s there was a decision to separate science (risk assessment) from policy (risk management). This was in part a reaction to the politicization of science, in the early 1980s. The decision was also based on the assumption that “experts” were the most suited to weigh uncertain scientific evidence. The science-based decision-making paradigm keeps environmental debates within a “dispassionate” scientific framework.

In response to this, sociologists and scientists have developed theories for science used in environmental policy, calling them “trans-science”; “mandated science,” or “post-normal science.” All of these models recognize that *decision making regarding hazards in the face of uncertainty is complex, value-laden, and contentious.* Scientific information and procedures play an important role in the process but do not resolve difficulties and uncertainties. Too often they provide a misleadingly rational and idealistic view of the policy process. Rather than following a linear, rational process, such decision making must be more like solving a puzzle: gathering bits of incomplete information from many sources, looking for patterns, and making intelligent guesses to arrive at solutions.

Uncertainty can pose an obstacle to rational, science-based decision making. It is often mistakenly viewed as a negative form of knowledge, an indicator of poor quality science. This is because acknowledging uncertainty can weaken government authority, by creating an image of the agency as ignorant, by threatening the objectivity of science-based standards, and by making it more difficult to defend itself in the face of challenges. As a result governments may be forced to use rationality and numbers as a facade to cover up essentially political decisions. It may also force governments to wait for more defensible proof of harm before acting, in order to avoid conflict. It is often in the interest of those fighting regulation to convert political questions into technical/scientific ones so as to avoid scrutiny. Finally, under uncertainty there is a tendency to focus on the more immediate, easily quantifiable costs to those creating risks rather than the less quantifiable, long-term costs of those affected by environmental degradation. Uncertainty becomes a reason to justify inaction. Because uncertainty is underappreciated, early warnings about potential harm are often overlooked.

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Biographical Sketch

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