Precautonary Limits to Environmental Science and Risk Management – Three Types of Errors

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ABSTRACT: *The twain, or interface, between public environmental policy making and environmental science does not facilitate each other in a constructive and cost-efficient way at present. The precautionary principle can be seen as an attempt to litigate and accelerate this situation. The role of science and uncertainties has been in the focus of the discussion - both for and against - the precautionary principle. Traditionally science, and unfortunately also environmental science, has focused on the reduction of risks for Type I errors (false positive rejection of the null hypothesis). Lately, the risk of Type II errors (false negative, failure to reject the null hypothesis) has been discussed in relation to managing the precautionary principle. However, both these approaches ignore the risk of Type III errors (accurate answer – wrong question), a qualitative estimate of the quality of the twain between science and public policy making. This paper, argues that the limitations of precautionary policy making might not solely be a result of uncertain science, but rather regulatory and scientific negligence of Type III errors, and lack of interdisciplinary perception from both the scientific as well as the regulatory communities. This can lead to* non-*precautionary decision-making.*

Keywords: Type I, II & III errors, Precautionary principle, Role of science.

Introduction

At the 23rd annual North American meeting of the Society of Environmental Toxicology and Chemistry (SETAC) 16-20/11-02 in Salt Lake City, UT, USA, keynote-speaker William Ruckelshaus, first administrator of the U.S. Environmental Protection Agency from 1970-73, made some interesting observations on science's role in environmental management and public policy. Modern science and democratic administration are siblings originating from the French and American revolutions in the 16th and 18th centuries. Presently, the twain (for science and public environmental policy) do not meet in a productive and creative way, and thus do not effectively understand and support each other, resulting in the failure of resource management (Ruckelshaus, 2002). Indeed, this is truer than ever in the realm of the interpretation and implementation of the precautionary principle/approach in environmental and risk management.

The most widely adopted versions of the precautionary principle/approach are variations on principle 15 of the Rio Declaration on sustainability which states that under threats of serious or irreversible harm, lack of full scientific certainty should not postpone the implementation of action to prevent degradation of the environment (Rio, 1992). Since then there has been much debate, and interest from governmental bodies on the interpretation of the precautionary principle/approach, and on how to define full scientific certainty in environmental issues (EU Com, 2000) (Canada, 2001) (EEA, 2002) (OECD, 2002). More popularly, the precautionary principle/approach is seen as a preference to err on the side of caution, rather than assume that the assimilative capacity of the environment will be able to absorb a potential damage (OECD, 2002).

Marchant (2001) argues that regulators and decision-makers must base their decisions on intelligible principles to provide consistency, predictability, transparency, and accountability to balance risk and cost-benefits. Further, due to the scientific uncertainty in complex environmental matters, and the vagueness in interpretation of the precautionary principle/approach, and the fact that it is not yet developed into customary international law, the precautionary principle is not presently applicable as a management tool (Marchant, 2001). Uncertainties in science in relation to environmental issues have been the critical point of the precautionary principle, simultaneously both justifying and limiting the implementation of the precautionary principle/approach. However, addressing uncertainty in precautionary risk management and decision-making processes is generally neglected and not mentioned by the EU, OECD, and Canada.

Public Environmental Policy Making

According to Shrader-Frechette and McCoy (1993), in situations of uncertainty, ecologists following a scientific account of rationality typically tend to minimize Type I errors, rejecting a null hypothesis when it is in fact true (false positive), rather than Type II errors, accepting the null hypothesis when it is in fact false (false negative) (Sanderson and Petersen, 2002). Type I errors can be thought of as being over protective - or fishing with too fine fishing mesh sizes and catching too many undersized fish. Type II errors can be seen as being over selective – or fishing with too large mesh sizes and thus not catching many fish of the right size. Type III errors (correct answer – wrong question), as we will return to, on the other hand can be conceived as fishing where there are no fish at all. That is, in terms of probabilities, the risk assessor and the regulator prefer the risk of not rejecting a potentially hazardous activity to the risk of rejecting a harmless activity. On the other side, consumers and the public in general tend to support a precautionary concept of rationality where uncertainty exists. They tend to question the null hypothesis and prefer Type I errors to Type II errors when both cannot be prevented. The preference for Type II errors among risk assessors and risk managers might partly arise from wanting to appear consistent with scientific practice and protective towards innovation, economy, employment, politics, and legal issues (Shrader-Frechette and McCoy, 1993). Frequently, environmental decisions are reduced to a search for so-called least cost options, which necessitate monetizing the decision criteria. However, the distribution of information and certainty between costs of Type I and II errors is asymmetrically skewed towards the high costs of the first and low costs of the latter (Stahl *et al.*, 2002). Finally, one of the most serious challenges to rational decision-making in environmental management is the criticism that individual managers face if they admit uncertainty, or if their decisions lead to unfavourable outcomes (Peterman and Anderson, 1999). The risk of Type II errors and its relation to uncertainty in environmental issues is not explicitly mentioned by any of the legislative bodies mentioned above in relation to precautionary principle/approaches.

Concerns have been expressed by the business community that the application of precautionary measures which are not based on sound science, or sufficiently supported by scientific evidence, may *inter alia,* threaten economic interests, add significant transaction costs, and distract resources from better understanding and resolving the environmental issues in dispute. Similar concerns have been expressed by representatives of both the developed and developing countries (OECD, 2002). According to the World Trade Organization (WTO) Appellant Body, members are free to adopt their own policies aimed at protecting the environment as long as, in so doing, they fulfill their obligations and respect the rights of other members under the WTO Agreement (Marceau, 2002). In the EU, implementation of the Precautionary Principle must be non-discriminatory towards other member states and in accordance with the Proportionality Principle (EU Com, 2000). There is no agreed view on the role of precaution in the process for risk analysis (risk analysis consists of following three inter-related components; risk assessment, risk management and risk communication) (OECD, 2002). The European Union considers that precaution is particularly relevant to the management of risks (EU Com, 2000). For the United States, precaution is a feature of both risk assessment and risk management, thus, inherent throughout risk analysis (OECD, 2002). Obviously, the challenge of balancing the freedom and rights of individuals, industry and organizations with the need to reduce the risk of adverse effects on human, animal or plant health and the environment fosters strong economic and political opponents, and political opportunitism when analyzing the implementation of precautionary principles/approaches.

The Role of Science

The core of the debate for and against the precautionary principle/approach from a scientific point of view has been over the management of scientific uncertainty and thus the limits of science. While science provides a vital input to environmental management, the focus has been to separate what science can do from what it cannot. Science can help define a problem, and often it can help determine the appropriate solutions. However, science alone cannot decide on whether to seek a solution in the first place, or how to define an acceptable solution. Science plays an important role in analyzing and assessing a risk and in informing decision-makers about alternative approaches and the potential consequences and costs of actions taken (or not taken), but management of the risk and balancing the different factors in play is the responsibility of decision-makers (OECD, 2002). Reports on the limits of management are more infrequent. Yet, Underwood (1995) states that scientists need to respond to criticisms of scientific credibility when the uncertainties in science are misunderstood. Uncertainty is an inevitable conclusion of ecological investigations, and indeed of science. Physicists have openly claimed to deal with uncertainty in all their science. This has not caused them to be accused of being incompetent or inadequate. Hence, it is important not to confuse uncertainty with quality in science. It is impossible to prove negative assertions *e.g.* proof of lack of effect of a chemical. The basis for this can be found in Karl Popper's falsification theory. If a theory withstands a series of falsification attempts (99% of science attempting to falsify the remaining 1% of science), then the theory is accepted until it is eventually falsified and replaced but a better theory or model. The conclusion is that environmental acceptance can only be demonstrated by induction – it becomes a question of confidence and values. This is reflected in requirements to authorities to perform adequate investigations to accept that an activity or chemical is harmless relative to societies chosen level of protection (Harremoes, 2003).

The Twain

From the OECD definition of risk assessment limitations, we can separate the limits to risk management OECD (2002). Risk management cannot alone define a problem, nor can it alone determine appropriate solutions, and risk management plays a minor role in assessing and analyzing a risk. In standard texts on statistics there are the two types of errors. However, in 1968, the statistician Howard Raiffa first proposed a third type of error, Type III, solving the wrong problem but with precision (Raiffa, 1982). The risk of a Type III error is seldom debated in environmental issues. However, as Weinberger (1985), Peters (1991) and Underwood (1995) have stated, the risk of decision-makers committing Type III errors is certainly present and their likelihood is proportional to the decision-makers understanding of science and communication with the risk assessor. Environmental decision-making and risk management objectives are often unclear, the decision analysis is often not transparent, not formalized, nor harmonized and the analyses involve measures of outcomes in different units (dollars, mortality, diversity, mg L^{-1} etc) (Peterman and Anderson, 1999). This adds to the risk of Type III errors and the necessary understanding of the problems related to the specific scientific context, the terminology, epistemology, uncertainties, and risks of Type II errors. In Wynne (1992) definition of different kinds of uncertainty the Type III errors would sort under category three ignorance. Ignorance in this context is not so much a characteristic of scientific knowledge itself as of the linkages between knowledge and commitments based on it – in effect, bets (technological, social, and economic etc.) on the completeness and validity of that scientific knowledge in question. In this there is a risk to try to fit the solution to the problem and not the problem to the solution, as it should be. The risk of Type III errors can be elucidated and thus reduced *e.g.* by application of adaptive management procedures such as learning multiple criteria decision-analysis (Stahl *et al.*, 2002), and a series of other methods (Raiffa, 1982). The risk of Type III errors can be elucidated and thus reduced *e.g.* by application of adaptive management procedures such as learning multiple criteria decision-analysis (MIRA) (Stahl *et al.*, 2002), and a series of other methods (Walker et al., 2003), including Spatial Analysis and Decision Assistance (SADA version 3.0) (http://www.tiem.utk.edu/~sada/) models by the United States Environmental Protection Agency. Another example of approaches to reduce the risk of Type III errors is the introduction of post-normal science by Funtowicz and Ravetz (1994) (see http://www.nusap.net/). The post-normal approach stresses the importance of not confusing uncertainty in science with lack of quality in science, indeed highly qualified science should also illuminate the inherent uncertainty. This is applicable in environmental matters with high uncertainty and high stakes when the phenomena themselves are ambiguous and the mathematical techniques are open to methodological criticism (Funtowicz and Ravetz, 1994). This is supported by the German sociologist Niklas Luhmann (1927-1998) considerations of reflexive decision-making in environmental policy making is a good illustration of the precautionary principle as a dynamic and changeable decision making tool, which needs to be revised in light of new scientific knowledge or findings. Petersen (2002) concludes that scientific certainty is unattainable for the most important policy problems of the present day. Thus, supplementary technologies such as reflexive or post-normal science method development may be applicable if the stakes are high and methodological and epistemic uncertainties are the same. Epidemiological evidence alone can be proof beyond reasonable doubt, which in a court of law is sufficient to condemn the accused, and in society to justify action to reduce risk (Doll, 2002). Environmental science and risk assessments on the other hand traditionally focus on protection against Type I & II errors (Sanderson and Petersen, 2002) (Hornbaker and Cullen, 2003). In the light of knowledge gaps and uncertainties, and since human and ecological health both fall under the realm of the precautionary principle, and since human and ecological health are interlinked, the harmonization of null hypothesis testing focus (Type I vs. II error) as well as level (causality vs. correlation), and burden (government or producer) of proof could be argued for a more sustainable stewardship and *e.g.* substitution of hazardous chemical compounds.

The two siblings guiding modern society referred to by Ruckelshaus (2002) must be more compatible, in the case of implementing precautionary principles/approaches in the pursuit of sustainability. Focus on the shortcomings of science (uncertainty) should not exclude a similar debate over the shortcomings of public policy making (uncertainty and risk of Type III errors). Currently, the battles are over scientific uncertainty (risk of Type I errors and rarely risk of Type II errors) and to a far lesser extent policy-making uncertainty (risk of Type III errors). There is in other words a need for interdisciplinary analyses (Lowell, 2001), enhanced and open communication between risk assessors (typically scientists with context depended interpretation of uncertainty), and risk managers (typically lawyers with another context depended interpretation of uncertainty), in order to reduce the risk of Type II and III errors and increase the cost-effectiveness of environmental risk management (Sanderson *et al.*, 2002). The scientific and legal knot is to find a way or set criteria as to how to falsify a negative, or to prove something is not an unacceptable risk, as this approach reverses the burden of proof and contradicts traditional legal practises and potentially threats to jeopardize scientific objectivity. The asymmetrical distribution of scientific focus, information, certainty and valuation between acceptable risks of Type I and II errors increases the risk of *non*-precautionary Type III errors in public policy making hampering sustainability. The widespread lack of confidence in science, anxiety evocative of the risk society (Beck, 1992), and uncertainty regarding science's role in precautionary management, we would argue philosophically originates in the confusion of certainty and quality of science and ignorance of Type III errors. From a shortsighted legal, socio-economic and political point of view, Type I errors (producers risk) are unwanted because of the risk of legal cases and the resistance to hamper the producers' right and access to the market. Lack of knowledge or insight into Type II errors (consumers/environments risk) and resistance to Type I errors may lead to more or less realised Type III errors by addressing the wrong question, typically in a precautionary context focusing on *How*-questions rather than *Why*, or *What If*-questions, accepting that precautionary environmental science is not careless but aims for sustainability, and as such should not be as objective as studies of stellar movements. How a change in objectivity criteria will influence environmental science is unknown, a certain risk is increased popularism and risk of decisions based on wrong assumptions, which is why the decisions have to be adaptive. The current alternative is an environmental science (often simple practises and technologies for risk assessment) that is apart from its political and regulatory context and intent.

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