Human and Ecological Risk Assessment, 10: 787–799, 2004

ISSN: 1080-7039 print / 1549-7680 online
DOI: 10.1080/10807030490513801

The Precautionary Principle in the Information Society

Claudia Som,[1] Lorenz M. Hilty,[1] and Thomas F. Ruddy[2]
[1]Swiss Federal Laboratories for Materials Testing and Research, EMPA, St. Gallen, Switzerland; [2]Webster University, St. Louis, Missouri, USA

ABSTRACT

The Precautionary Principle aims to anticipate and minimize potentially serious or irreversible risks under conditions of uncertainty. Thus it preserves the potential for future developments. It has been incorporated into many international treaties and pieces of national legislation for environmental protection and sustainable development. However the Precautionary Principle has not yet been applied systematically to novel Information and Communication Technologies (ICTs) and their potential environmental, social, and health effects. In this article we argue that precaution is necessary in this field and show how the general principle of precaution can be put in concrete terms in the context of the information society. We advocate precautionary measures directed towards pervasive applications of ICT (Pervasive Computing) because of their inestimable potential impacts on society.

Key Words: precautionary principle, information society, sustainable development, uncertainty, technological risk.

INTRODUCTION

Novel technologies inspire in us the expectation of a better life, but simultaneously they bring about new risks. The increasing power of innovation makes it difficult to anticipate the implications of novel technologies in time (WBGU 1998). There is "a growing tension between two aspects of science: its growing innovative powers are increasingly outrunning its capacity to anticipate the consequences" (EEA 2001, p. 185).

Technical progress is accelerating and novel technologies are influencing our lives profoundly. Thus society has to find instruments to anticipate the consequences of novel technologies early enough in order to steer technological developments in the direction of a better life. When comparing new technological opportunities with risks, society faces repeatedly the basic question of the ethics of technology: Which technologies do we want in our lives, and what kind of a world would that be?

Received 25 June 2004; revised manuscript accepted 2 July 2004.
Address correspondence to Claudia Som, Swiss Federal Laboratories for Materials Testing and Research, Lerchenfeldstrasse 5, St. Gallen, CH-9014, Switzerland. E-mail: claudia.som@empa.ch

The Precautionary Principle (PP) may provide a framework to anticipate and minimize the risks of novel technologies as well as to foster their positive potential. It aims to minimize uncertain risks caused by human activities as early as possible and thus to keep a space open for future developments. The principle is normative in two senses: first, the subjects of protection and their values have to be defined based on a system of values, and second, the question of how much precaution society should apply is a matter of attitude.

During the early stages of environmental protection governments waited until full scientific certainty was available on risks before taking any action, an approach called *prevention*. Risks without complete scientific proof and long-term risks were underestimated or even ignored, and as a consequence, environment and human health suffered serious consequences (Reich 1989; EEA 2001; Wiedemann *et al.* 2001). Thereafter the PP gained importance in national regulations (Williamson and Hulpke 2000) and international treaties for environmental protection and sustainable development. It is expected to play an increasing role in the future (Graham 2001).

The following list shows some typical articulations of the PP occurring in international treaties and agreements (Raffensperger 1999; Sandin 1999; Ammann and Vogel 2001; EEA 2001):

- "Parties to this protocol . . . determined to protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it . . . " (Montreal Protocol 1987);
- "Accepting that, in order to protect the North Sea from possible damaging effects of the most dangerous substances, a precautionary approach is necessary which may require action to control inputs of such substances even before a causal link has been established by absolutely clear evidence" (Second North Sea Conference 1987);
- "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (The Rio Declaration on Environment and Development 1992);
- "The parties should take precautionary measures to anticipate, prevent, or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost" (United Nations Framework Convention on Climate Change 1992);
- "In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Protocol is to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account

risks to human health, and specifically focusing on transboundary movements" (Cartagena Protocol on Biosafety 2000);
- "Mindful of the precautionary approach as set forth in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Convention is to protect human health and the environment from persistent organic pollutants" (Stockholm Convention on Persistent Organic Pollutants 2001).

These articulations show three characteristics of the PP as it has been interpreted so far. First, the PP is a rather *open* principle. The "openness" of the wordings leaves room for democratic decisions, but also for arbitrary decisions and makes it difficult to operationalize the PP. Therefore there is an intensive debate going on about the utility of the Precautionary Principle (see, *e.g.*, Chapman 1999; Santillo and Johnston 1999; Applegate 2000; Graham 2000; Sand 2000; Kriebel *et al.* 2001; Conko 2003; Tickner *et al.* 2003).

Second, the PP is usually designed to defend specific *subjects of protection*, such as the ozone layer, the North Sea, the climate, biodiversity, the environment in general or human health. In exceptional cases, the PP refers also to specific *sources of impact* such as Persistent Organic Pollutants (POPs). However there is no formulation of the PP that addresses *specific technologies.*

Third, the subjects of protection that are addressed do not include the *social dimension (social practices and structures)*.

The same applies also to most national regulations referring to the PP (for a survey see Williamson and Hulpke 2000; Wiener 2002). We will show that an interpretation of the PP in the context of the information society makes it necessary to shift the perspective: In this case, we suggest using the PP as an instrument of technology assessment rather than to focus on specific impacts to specific subjects of protection. ICT has various types of potential impacts on many subjects of protection, including a social dimension in the first place. So we will look from the perspective of the technology (ICT) and the trend to apply it pervasively, as propagated by the vision called "pervasive computing," and try to put the PP into concrete terms in this context.

To refine the PP for application to a specific technology should facilitate its implementation. The refined principle could account for the specific characteristics of the technology of concern. This would have the advantage that precautionary measures could be applied early and well directed, thus averting irreversible negative developments cost-effectively. That way the Precautionary Principle can serve as a framework to set constructively the course for innovations (Ashford 1999; Santillo and Johnston 1999; Graham 2000; Kriebel *et al.* 2001; Stirling *et al.* 2001).

The following, second section of this article explains the general aim of the Precautionary Principle, independent of specific subjects of protection, impacts, or technologies. In the third section, we analyze the specific characteristics of ICT and its pervasive application in society. The fourth section shows the implications of the characteristics of ICT for the PP, when viewed from the perspective of the technology. The last section summarizes our conclusions.

THE AIM OF THE PRECAUTIONARY PRINCIPLE

The notion of the Precautionary Principle (PP) has not been clearly defined, but varying versions of it are expressed in international treaties and scientific literature (see, *e.g.*, Sandin 1999; Pittinger and Bishop 1999). The core idea of all versions is to avoid potentially serious and irreversible damage, aiming to anticipate harm or risks of harm (Cranor 2001). Renn *et al.* (2003, p. VI) describe the Precautionary Principle as "a general principle employed in the screening of threats for the properties of seriousness or uncertainty in order to determine their subsequent treatment in regulatory appraisal and management."

We understand the PP as a framework for decisions under uncertainty, which aims to anticipate and minimize potentially serious or irreversible risks. The absence of full scientific certainty should not inhibit action if otherwise severe damage could be caused. The later society takes action to minimize a risk, the higher the cost of prevention or repair. Furthermore, while society is waiting for full scientific proof of causality before deciding to take measures, irreversible developments may take place (Wingspread 1998; Lowell Statement 2001).

Precautionary action does not necessarily mean regulating, much less banning a technology. There are other important types of precautionary actions that are more directed to quickly reducing uncertainty by fostering scientific and public discourse, in particular:

- to "provide adequate long-term environmental and health monitoring and research into early warnings" (EEA 2001, p. 193),
- to listen to early warnings (EEA 2001) and to intensify interdisciplinary cooperation in order to detect early warnings (Lowell Statement 2001; Sanderson *et al.* 2002),
- to foster written scientific minority opinions (Hansson 1999),
- to invite civil society to participate not only in the risk assessment but also in the knowledge production process (WBGU 1998; EEA 2001),
- to examine the full range of alternatives (Wingspread 1998; EEA 2001; Keeney and Von Winterfeldt 2001).

Under conditions of uncertainty a risk may be overestimated ("Type I error" or "false positive"), or underestimated ("Type II error" or "false negative"). The European Environmental Agency (EEA 2001) investigated the history of both kind of errors and found that there was a bias of underestimating risks under conditions of uncertainty. Kriebel *et al.* (2001) presented an overview of scientific methodologies that skew scientific results in the direction of underestimating risks.

According to Hansson (1999) the minimal version of the Precautionary Principle consists in moving the decision-making in the direction of risk neutrality. Other authors advocate stronger versions of the PP and prefer under particular conditions to err on the side of caution (*e.g.*, Kriebel *et al.* 2001). Jonas (1979) even postulated his priority of the bad forecast, which could be called the maximal version of the PP.

Independent of the position one takes on a continuum between the minimal and the maximal version of the PP, let us investigate how this principle can be refined to be applicable to ICT.

CHARACTERISTICS OF ICT

Information and Communication Technology (ICT) differs from other technologies in that it directly affects communication processes and the distribution of information and knowledge. ICT is directly associated with the concept of an "information society," a notion, however, that is not clearly defined. We will use the term "information society" to denote the prospective outcome of a structural change in society stimulated by the close interaction between social practices and ICT. The development and use of ICT and social practices are interdependent.

The application of ICT is expected to become pervasive within about a decade, that is, all aspects of daily life may be influenced by networked ICT components (Pervasive Computing). From the perspective of technology assessment, the combination of the following characteristics of ICT is important for their potential implications:

- ICT is a mass consumer technology that enables the user to gain access to communication channels, information, and the control of processes.
- ICT components will increasingly be embedded in other objects that will then take on "intelligent" features, but will not be perceived as ICT devices (98% of all presently existing programmable microprocessors are embedded; Broy and Pree 2003).
- There is a trend to interconnect the physical world (world of things) with the virtual world (world of data) in real time, that is, more and more data will be synchronized with physical processes via sensors, and *vice versa* via actuators. The opportunities this synchronization brings about for the organization of production and consumption processes tend to make us dependent on its availability and proper functioning.
- The diffusion of novel ICT depends strongly on compatibility issues. The requirement that new ICT products remain compatible with existing ones narrows the range of future development trajectories. Therefore, the market development of ICT is highly path dependent. In fields where no open technical standards have been established (*e.g.*, word processing), ICT markets tend toward a "winner takes it all" structure.
- ICT systems form complex distributed systems when networked. The responsibility for damages caused by ICT is as distributed as the technology itself. This leads to a dissipation of responsibility—a new version of the same "organized lack of responsibility" that the German sociologist Ulrich Beck attributed to modern technologies (Beck 1986/1992).

For these reasons, ICT is expected to interact intensively with social practices, which may result in profound changes to social rules and structures in the near future. Some issues can be viewed as precursors of this development, for example, the so-called digital divide, which consists of excluding part of society from access to ICT, or the fact that privacy regulations are increasingly difficult to implement, because technology is advancing faster than the legal system can react to it.

PRECAUTION IN THE INFORMATION SOCIETY

Basically, a society with better access to information will also have the advantage of perceiving risks earlier. The more freely people can access information, the more unlikely it is that the public will refrain from disputing new risks until the scientific investigation is completed (EU 2000).

This leads to a discerning attitude against novel technologies and an increasing demand for the application of the PP (EEA 2001). Thus political decision-makers have to allow for this increased public risk perception. From this perspective, a risk can be viewed as a phenomenon that arises simultaneously out of the physical and the social world (Macgill and Siu 2004). Future ICT will amplify this trend.

But besides this role of ICT in risk perception, ICT is also a source of risk on its own. The latest vision of future ways of applying ICT to our daily lives, Pervasive Computing, involves the miniaturization and embedding of microelectronics in non-ICT objects and wireless networking, making computers ubiquitous in the world around us (see also Hilty *et al.* 2003). In order to show how this technology challenges the idea of precaution, we present three examples of unintended effects of ICT.

Example 1: Stand-by Power Consumption

The innovation of remote control for consumer electronics caused continuous power consumption by numerous consumer electronics devices such as television sets. This additional power consumption now accounts for a significant share of total power consumption. This trend is expected to be accelerated by future ICT.

Example 2: NIR Exposure Caused by an Increasing Number of Wireless Communication Devices

Many countries have established precautionary limits for the non-ionizing radiation (NIR) emitted by the base transceiver stations of mobile phone networks. The average exposure is likely to increase with Pervasive Computing due to the high number of mobile and wearable NIS emitters. There is a conflict potential, as non-users of Pervasive Computing may subjectively see themselves exposed to impairments caused by others.

Example 3: The Feeling of Being Under Surveillance

Pervasive computing enables the use of almost invisible electronic surveillance devices. The intended ubiquity of networked electronic devices will systematically blur the distinction between undesirable surveillance systems and desirable service systems. Assuming that spying incidents will emerge—some of them causing spectacular scandals—this appears likely to lead to a climate of distrust.

We have presented these examples to prompt a discussion of the general causation structures behind the unintended effects mentioned. We first want to ask the question: What precautionary measures could have prevented these unintended effects from emerging?

Referring to the traditional interpretation of the PP that is rooted in environmental protection, precautionary measures have to be taken right at the source of

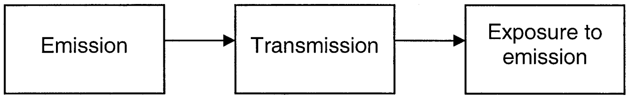

Figure 1. Causal chain of hazardous impacts on the environment.

emissions (Figure 1), as opposed to preventing a subject of protection from exposure once emissions have been released.

Applying this principle to Example 1, we would have to ensure that the power consumed by electronic devices be produced in the most environmentally compatible way, that is, with minimal emissions. However, one could expect intuitively that precaution should also address the power consumption itself, in particular given the fact that technical solutions for minimizing stand-by losses exist. If the PP had been observed, these (favorable) technologies would have been diffused instead of the inefficient ones, which were unfortunately built into almost all consumer electronics appliances.

As the example shows, it is necessary to extend the causal chain in order to allow for a useful re-interpretation of the PP. An extended causal chain is shown in Figure 2, including availability, diffusion, and application of the technology as well as user behavior (Hilty *et al.* 2003).

Examples 2 and 3 make the necessity of taking this broader perspective even more evident.

The basic normative question arises as to where the appropriate place in the model is for precautionary measures to be taken. If one takes them too early in the causal chain (just as a technology emerges, in the extreme case) a development can be hindered and freedom limited in an excessive manner. If, on the other hand, one chooses a later point of intervention, irreversible conditions might then be no

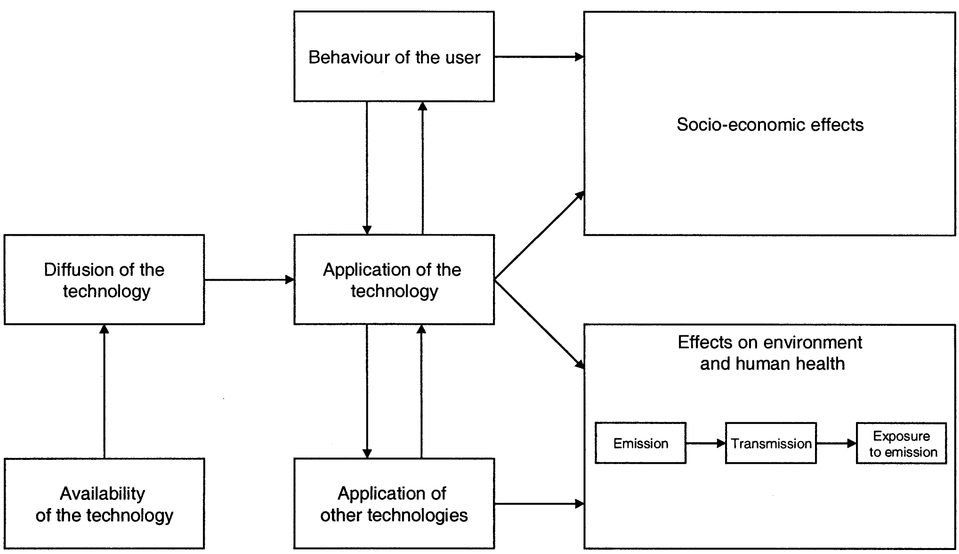

Figure 2. Expanded model of the causal chain.

longer preventable.[1] We do not offer any answer to this question here, because it is a normative decision that requires a consensus in a democratic society. However we would like to go into more detail on the irreversibility aspect, which is closely associated with the PP. The irreversibility addressed here is not based on the laws of natural science, but on socioeconomic conditions (socioeconomic irreversibility). This phenomenon is also known as lock-in (Rammel 2003; Rip *et al.* 1995).

Several causes of this type of irreversibility (concerning the diffusion and application of novel technologies) are discussed in the literature:

- Raising the cost of shifting to alternatives.
- The expected return on investment: Investments in research and development are strong drivers of sales; private-sector companies need to sell their new products to get the return on their investments.
- Adoption by users: Numerous users accustomed to a technology are probably not ready to give it up (such as the QWERTY keyboard).

Due to socioeconomic irreversibility, cost-efficient and reasonable precautionary measures probably have to be applied early in the causal chain, that is, the “source of emissions” is no longer the right place.

The characteristics of ICT mentioned in the preceding section strengthen the socio-economic irreversibility of this technology, which makes it a likely candidate for having a PP applied to it that considers an extended causal chain: embedding, dependency, development paths forced by compatibility requirements, and a distribution of responsibility that will be difficult to reverse.

As we have shown by way of Examples 2 and 3, emissions are not the only type of potentially negative effects of ICT. Looking again at Example 2, we understand that conflicts and fears may arise in society that may in turn cause stress. The feeling of being under surveillance, mentioned in Example 3, may also lead to stress. As it is known that stress can cause measurable adverse health effects, there is no obvious reason to exclude stress from the effects considered when applying the PP to ICT, while including toxic emissions.

It follows that if the PP is to be applied from the perspective of a particular technology, all types of impacts on all relevant subjects of protection have to be considered *a priori.* In particular, it seems arbitrary to draw a borderline between social and health effects, because they are tightly intertwined, as are social and environmental effects (social practices affect the environment, and *vice versa*), and environmental and health effects (pollution affects health, health care can pollute the environment). It is obvious that a PP interpreted in that way will no longer be part of environmental regulations in particular, but would have to become anchored in many parts of legislation such as, for example, consumer regulations.

---

[1]Ropohl (1996) propagated the concept of *innovative technology assessment*, which takes place in a very early phase of technology development where a vision of use is introduced. The advantage of it is that technology assessment takes place at the origin where substantial technological knowledge is available. The disadvantage is that, in this early development phase of a novel technology, forecasting risks is difficult. Thus Ropohl (1996) proposes that innovative technology assessment should be done concurrently with technology development and create a continuous interactive learning process.

ICT also has the potential to change legal practice, because the basic principle that the party responsible is liable for damages (causation principle) is increasingly difficult to enforce in environments controlled by Pervasive Computing. As a rule, it is not possible to isolate the cause of damages due to the combined effects of several components from computer hardware, programs, and data in networks, as it is practically impossible to cope with the complexity of such distributed ICT systems, neither mathematically nor legally.

As society's dependence on systems of this kind will grow with Pervasive Computing, a net increase in the damage derived from unmastered technical complexity has to be expected. As a consequence, a growing part of day-to-day life will, virtually, be removed from liability. Thus, ICT has the potential to undermine existing regulation.

The idea that new technologies may interact with society's basic value system, that is, have influence on the "coordinate system" in which opportunities and risks are evaluated, including moral principles (Van den Daele 1991, cited in Wiedemann and Brüggemann 2001), seems quite real when we consider the vision of Pervasive Computing.

From this point of view it seems unacceptable for part of a democratic society (*i.e.*, the producers of ICT) to have the opportunity to create a *fait accompli*, that is, initiate far-reaching changes that have not been the subject of reflection by the whole society before then. Therefore, a dialogue on the development trajectories of future technologies and their implications should be established in society.

Dealing with Uncertainty

The PP applied from the perspective of a technology has *inter alia* the effect that society becomes aware that there is any choice. However, it is difficult to make a choice under conditions of uncertainty, in particular a collective choice in a pluralistic society requiring a consensus or a democratic majority. Two basic strategies to deal with this problem are discussed in the context of the PP.

The first strategy is to keep as much space for future development open as possible. This means that the irreversibility criterion is given first priority in evaluating uncertain risks. In the context of environmental law, this strategy is known as the "open space theory" (Beyer 1992). It is related to the idea of sustainable development, which says that the needs of the present should be met "without compromising the ability of future generations to meet their own needs" (WCED 1987). This implies keeping as much space for future decisions open as possible because we cannot anticipate today what the needs of future generations will be. Rammel (2003, p. 397) claims that "the purpose of sustainability is to foster socioeconomic trajectories that . . . contain the potential to achieve continuous and stable developments." Where environmental problems are concerned, it seems plausible that resource conservation and avoiding pollution work to the advantage of "open space" and therefore sustainability. However, when we try to apply the same general principle to a technology, namely ICT, the situation becomes more complex. Shall the rich countries, for instance, help poor countries get access to the Internet because this creates opportunities for development, or might this lead to a socioeconomic and cultural lock-in that should be avoided? The example shows that there are no simple answers to the question of what a "sustainable information society" should be like. However, it can be argued that the basic requirement for sustainability is adaptive flexibility, meaning the possibility to initiate new development trajectories. Adaptive flexibility is enhanced by diversity (Rammel 2003). It follows that a basic precautionary heuristics is to preserve diversity and avoid path-dependency. For the application of the PP to ICT, we can conclude:

- Open standards for all types of interfaces among ICT products are preferable over proprietary standards, because they are essential for avoiding strong path-dependency and trends toward market dominance, which destroy diversity.
- Less complex technical solutions should generally be preferred to more complex ones, because unmastered technical complexity fosters investment in analysis and adaptation, which fosters the path-dependency of the development.

The second strategy is participation (for an overview see Rip *et al.* 1995; EUROPTA 2000; Joss and Bellucci 2002; Renn *et al.* 2003). Involving all stakeholders (producers and users of the technology, insurance companies, governmental and nongovernmental organizations, *etc.*) in a dialogue on the development and application of novel technologies is known to aid in detecting early warnings, preventing conflicts, and developing safer products. A stakeholder dialogue on technology development could even lead to a "new production of technology" yielding "socially robust technology" (as opposed to only technically robust technology), in analogy to Helga Novotny's concept of the "new production of knowledge" or "Mode 2 science" leading to "socially robust knowledge" (Novotny *et al.* 2001, 2003). Participation in a dialogue on novel technologies, however, is only possible if there is a basic ability to reflect on present technology and technological visions, which is usually lacking in the ICT field. Therefore, an essential aspect of precaution is in this case to provide a type of education that will give people the capacity to critically reflect on ICT and its impacts.

CONCLUSIONS

We have explained why we think that precaution is necessary in the ICT field, particularly when we consider the vision of Pervasive Computing. We have shown how the general idea of the Precautionary Principle can be put into concrete terms in the context of the information society. The Precautionary Principle in the information society can be articulated as follows: In order to enable society now and in the future to make relevant choices in the use of Information and Communication Technologies, as well to minimize harm for human health and the environment caused by ICT, ICT-related decisions under uncertainty should favor

- lower complexity over higher complexity,
- open standards over proprietary standards, and
- adapting the technology to humans over adapting humans to the technology.

ACKNOWLEDGMENT

The authors thank Prof. Dr. Beat Sitter-Liver, University of Fribourg and Swiss Academy of the Human and Social Sciences (SAGW), and Prof. Heinrich Kuhn, Zurich University of Applied Sciences Winterthur (ZHW), Competence Center for Risk Prevention, for their very detailed discussions.

REFERENCES

Ammann D and Vogel B. 2001. SAG—Studienpapiere, Basisdokumente, Expertisen, Argumentationen, B6—März 2001, Vom Risiko zur Vorsorge, SAG Geschäftsstelle (Schweizerische Arbeitsgruppe Gentechnologie), zypresse, Zurich, Switzerland

Applegate J. 2000. The precautionary preference: an American perspective on the precautionary principle. Hum Ecol Risk Assess 6:413–43

Ashford NA. 1999. A conceptual framework for the use of the precautionary principle in law. In: Raffensperger C and Tickner JA (eds), Protecting Public Health, Implementing the Precautionary Principle, pp 198–206. Island Press, Washington, DC, USA

Beck U. 1986 and 1992. Risikogesellschaft. Auf dem Weg in eine andere Moderne. Suhrkamp, Frankfurt, Germany

Beyer HM. 1992. Das Vorsorgeprinzip in der Umweltpolitik. Schriftenreihe Wirtschafts- und Sozialwissenschaften, vol 10. Verlag Wissenschaft & Praxis

Broy M and Pree W. 2003. Ein Wegweiser für Forschung und Lehre im Software-Engineering eingebetteter Systeme. Informatik-Spektrum, February 2003, pp 3–7

Cartagena Protocol on Biosafety, Article 1, Objective 2000. Available at http//:www.biodiv.org/biosafe/BIOSAFETYPROTOCOL.htm

Chapman PM. 1999. Does the precautionary principle have a role in ecological risk assessment? Hum Ecol Risk Assess 5:885–8

Conko G. 2003. Safety, risk and the precautionary principle: rethinking precautionary approaches to the regulation of transgenic plants, Transgenic Res: 1–9. Available at http//:www.cei.org/pdf/3708

Cranor FC. 2001. Learning from the law to address uncertainty in the precautionary principle. Science and Engineering Ethics 7:313–26

EEA (European Environmental Agency). 2001. Late Lessons from Early Warnings: The Precautionary Principle 1896–2000. EEA Copenhagen, Denmark. Available at http://reports.eea.eu.int/environmental_issue_report_2001_22/en) dated 5.11.2002

EU (European Union). 2000. Mitteilung der Kommission. Die Anwendbarkeit des Vorsorgeprinzips KOM (2000) 1 endgültig. Brussels 2.2.2000. Available at http//:www.europa.eu.int/comm/trade/whats_new/dpp_de.htm

EUROPTA. 2000. European Participatory Technology Assessment; Participatory Methods in Technology Assessment and Technology Decision-Making. Danish Board of Technology. Report Available at http//:www.tekno/dk/europta October 18, 2000

Graham JD. 2000. Perspectives on the precautionary principle. Hum Ecol Risk Assess 6:383–385

Graham JD. 2001. A future for the precautionary principle? J Risk Res 4:109–111

Hansson SO. 1999. Adjusting scientific practices to the precautionary principle, Hum Ecol Risk Assess 5:909–21

Hilty LM, Behrendt S, Binswanger M, *et al.* 2003. Das Vorsorgeprinzip in der Informationsgesellschaft. Auswirkungen des Pervasive Computing auf Gesundheit und Umwelt. Study on behalf of the Swiss Center for Technology Assessment (TA-SWISS), Bern, Switzerland (TA 46/2003)

Jonas H. 1979. Das Prinzip der Verantwortung. Versuch einer Ethik für die technologische Zivilisation, Frankfurt, Suhrkamp

Joss S and Bellucci S. 2002. Participatory Technology Assessment, European Perspectives. Centre for Study of Democracy University Westminster, Swiss Center for Technology Assessment

Keeney RL and Von Winterfeldt D. 2001. Appraising the precautionary principle—a decision analysis perspective. J Risk Res 4:191–202

Kriebel *et al.* 2001. The precautionary principle in environmental science. Environ Health Perspect 109:871–76

Lowell Statement. 2001. Available at http://www.biotech-info.net/final_statement.html

Macgill SM and Siu YL. 2004. The nature of risk. J Risk Res 7(3):315–52

Montreal Protocol. 1987. Protocol on Substances that Deplete the Ozone Layer, S. Treaty Doc. No. 10, 100th Cong., 1st sess., 26 I. L. M. 1541 (September 16, 1987)

Novotny H, Scott P, and Gibbons M. 2001.Re-thinking science: knowledge and the public in an age of Uncertainty. Cambridge: Policy Press

Novotny H, Scott P, and Gibbons M. 2003. Introduction: "Mode 2" revised: the new production of knowledge. Minerva 41:179–94

Pittinger CA and Bishop WE. 1999. Unraveling the chimera: a corporate view of the Precautionary Principle. Hum Ecol Risk Assess 5:951–62

Raffensperger C. 1999. Uses of the Precautionary Principle in International Treaties and Agreements. Available at http://www.biotech-info.net/treaties_and_agreements.html

Rammel C. 2003. Sustainable development and innovations: lessons from the Red Queen. Int J Sustainable Develop 6:395–416

Reich A. 1989. Gefahr-Risiko-Restrisiko; das Vorsorgeprinzip am Beispiel des Immissionsschutzrechts. Umweltrechtliche Studien 5. Werner Verlag, Munich, Germany

Renn O *et al.* 2003. The Application of the Precautionary Principle in the European Union, Final Document, EU-project: Regulatory Strategies and Research Needs to Compose and Specify a European Policy on the Application of the Precautionary Principle (PrecauPri)

Rip A, Misa TJ, and Scott J (eds). 1995. Managing Technology in Society, The Approach of Constructive Technology Assessment. Pinter, London, UK

Ropohl G. 1996. Ethik und Technikbewertung, Suhrkamp taschenbuch wissenschaft

Sand PH. 2000. The precautionary principle: a European perspective. Hum Ecol Risk Assess 6:445–58

Sanderson H, Ravetz J, and Tickner J. 2002. Scientific application of the precautionary principle. SETAC Globe, Oct 2002, pp 25–6

Sandin P. 1999. Dimensions of the precautionary principle. Hum Ecol Risk Assess 5:889–907

Santillo D and Johnston P. 1999. Is there a role for risk assessment within the precautionary legislation? Hum Ecol Risk Assess 5:923–32

Second North Sea Conference Ministerial Declaration, VII. 1987. Ministerial Declaration calling for Reduction of Pollution

Stirling A, Renn O, Klinke A, *et al.* 2001. On Science and Precaution In the Management of Technological Risk, An ESTO Project Report Prepared for the European Commission—JRC Institute Prospective Technological Studies, Seville, Spain

Stockholm Convention on Persistent Organic Pollutants (POPs). 2001. Article 1, Objective

The Rio Declaration on Environment and Development, Principle 15. 1992. Available at http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163

Tickner J, Kriebel D, and Wright S. 2003. A compass for health, rethinking precaution and its role in science and public health. International J Epidem 32:489–92

United Nation Framework Convention on Climate Change, Article 3 Principle, 3, 1992. Available at http://unfccc.int/resource/docs/convkp/conveng.pdf

WBGU. 1998. Welt im Wandel—Strategien zur Bewältigung globaler Umweltrisiken. Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, XXIV p 378, ISBN 3-540-65605-7. Springer-Verlag, Berlin, Germany, 1999

WCED (World Commission on Environment and Development). 1987. Our Common Future. Oxford Press, Oxford, UK

Wiedemann PM and Brüggemann A. 2001. Vorsorge aus der Perspektive der Sozialwissenschaft: Probleme, Sachstand und Lösungsansätze, Arbeit zur Risiko-Kommunikation, vol 82. Forschungszentrum Jülich GmbH, Programmgruppe Mensch, Umwelt, Technik. Jülich, Germany

Wiedemann PM *et al.* 2001. Risikopotentiale elektromagnetischer Felder (Bewertungsgrundsätze und Vorsorgeoptionen), vol 1. Forschungszentrum Jülich GmbH, Programmgruppe Mensch, Umwelt, Technik. Jülich, Germany

Wiener JB. 2002. Precaution in a multirisk world. In: Paustenbach DJ (ed), Human and Ecological Risk Assessment: Theory and Practice, pp 1509–31. Wiley, New York, NY, USA

Williamson GH and Hulpke H. 2000. Das Vorsorgeprinzip, Internationaler Vergleich, Möglichkeiten und Grenzen, Lösungsvorschläge. UWSF- Z.Umweltchem. Ökotox 12(1): 27–39

Wingspread Conference. 1998. Wingspread Statement on the Precautionary Principle. Conference on Implementing the Precautionary Principle. Racine, WI. January 23–25, 1998