Conference Paper

Type II ambiguity and precautionary screening with respect to large-scale chemical threats in the environment

Author(s):
Müller-Herold, Ulrich

Publication Date:
2002

Permanent Link:
https://doi.org/10.3929/ethz-a-004486581

Rights / License:
In Copyright - Non-Commercial Use Permitted

This page was generated automatically upon download from the ETH Zurich Research Collection. For more information please consult the Terms of use.
1. Risk and Ambiguity

In risk assessment socio-political ambiguity denotes the variability of legitimate interpretations based on identical observations or data assessments. Many of the disputes in the fields of risk analysis and management do not refer to differences in methodology, but to the question of what a presumed risk means for human health and environmental protection: Does it involve perceptions of major potential harm? Is it associated with significant institutional conflict or political mobilisation? Are there issues of “distributional equity” or signs of “social amplification” in the news media?

At present, electrosmog may serve as an illustrative example. The scientific mainstream, on the one hand, is predominantly sceptical about the adverse effects of low-frequency electromagnetic fields and the insurance business widely classifies them as “phantom risks”. In segments of the general public and of the news media, on the other hand, electromagnetic fields are seen as major sources of impairment, including carcinogenicity.

In contrast to socio-political ambiguity – which will be denoted as type I – there is a second form of ambiguity which applies to risk research itself. This second type of ambiguity has to do with the way sciences organize the inquiry of a potential risk. A potential environmental threat such as climate change or ozone depletion does not appear in scientific terms from the very beginning. Instead, it appears as a potential fact of everyday life that necessarily has to be reformulated as a scientific problem prior to scientific investigation. However, due to the highly-specialized, “balkanized” structure of the scientific world it is not clear a priori which of the conceivable disciplines will take ultimate responsibility in the shaping of a presumably multidisciplinary research process. 

This type of ambiguity will be called of type II.

The history of the greenhouse gases and climate change may serve as an illustration for type II ambiguity. In the early eighties they were seen mainly as problems of environmental chemistry. It was then, that the chemical dynamics of the greenhouse gases in the atmosphere was in question. However, once some probably dominant chemical mechanisms had become plausible, the main interest shifted to prediction: would there be a climate change at all? And if so, to what extent could it be influenced by reductions of greenhouse gas emissions? As environmental chemistry does not offer an obvious route to the investigation of these problems, the leading responsibility changed from

---

2 This problem was brought to the author’s attention by Silvio Funtowicz
chemistry to the group of “modellers” which purport to synthesize all the relevant knowledge.³

2. Precautionary action and chemical assessment

The appraisal of potential adverse effects of new and existing chemicals is one of the most tedious and costly burdens of innovation in the chemical industry. Although both industry and regulatory agencies have called for an overhaul of the relevant procedures there is no general call for the development of new and more efficient assessment tools by regulatory ingauthorities. The recently published EU’s White Paper on a Strategy for a Future Chemicals Policy⁴, for example, exclusively mentions classical risk assessment in connection with a quest for more data, more regulation, more costs and more responsibility for industry.

As we intend to look at the situation under the aspect of type II ambiguity, it is imperative to take a short look at on standard chemical assessment. This can be summarized as a four-step procedure:⁵

1. **Substance properties and emissions.** The first step starts with the characterization of chemicals in terms of their physicochemical properties, such as the vapour pressure, the octanol-water partition coefficient, the Henry’s law coefficient and rate constants for the various degradation processes in the environment. These chemical properties reflect intrinsic chemical properties of the chemicals in question.

2. **Exposure:** After emission, many different kinds of transport and transformation processes take place in the environment. The processes are governed by the intrinsic properties of a chemical in combination with environmental factors such as temperature, humidity, presence or absence of oxygen, etc.; they determine the concentrations at which the chemicals occur in the environment and to which organisms or ecosystems are exposed.

3. **Effects.** Exposure to chemicals causes a variety of effects in the environment, which are investigated by methods of toxicology and ecotoxicology. Here, it is the objective to causally relate effects to concentrations and to derive dose-effect relationships that, in turn, are used to define threshold values for the occurrence of adverse effects.

4. **Prediction.** The scientific results thus derived are assumed to reliably predict a chemical’s environmental fate and impact.

---

³ This shift in disciplinary leadership was emphasized by Silvio Funtowicz, who also raised the question of what kind of science modelling really is. There seems to be some literature about tensions between empirical scientists (natural and social) and modellers.


This practice was carefully discussed by Scheringer who emphasizes the impossibility to test for the reliability of the above assessment scheme under real environmental conditions. This has to do with an aspect Scheringer calls overcomplexity: overcomplexity due to the virtual infinity of possible biological effects and overcomplexity due to the undeterminable diversity of the environment itself.

The sequential nature of the assessment scheme, on the other hand, implies almost inevitably that the overall outcome of chemical risk assessment is dominated by toxicology and (to a lesser extent) by ecotoxicology, i.e. to the disciplines doing the concluding synthesis of the relevant results. In more technical terms, one speaks of so-called toxicological and ecotoxicological “endpoints” that are controlled by these disciplines. It is the endpoints which trigger regulatory decisions.

However, in view of these observations, one is confronted with the paradoxical situation that toxicology is the relevant discipline in chemical assessment in spite of the fact that the major insufficiencies of the overall procedure are due to the impossibility for toxicology to properly deal with biospheric overcomplexity. To some extent the situation is comparable to forensic psychiatry – many people criticize it, but some discipline has to do the job.

In the eighties, the quasi-monopolistic situation of toxicology was slightly changed when “ozone depletion potential” and “global warming potential” were established as novel, non-toxicological assessment endpoints. One realized that not only biological objects should be protected, but also non-living structures such as the atmosphere. However, as these new endpoints were again effect-based, this new and extended perspective was essentially in line with the earlier development. One simply had to think of the atmosphere as a novel kind of organism, species, or ecosystem to be protected.

3. Exposure-based precautionary pre-screening of new chemicals

Precaution-type arguments can be identified at several places in standard chemical assessment, particularly in the case of the well-known “safety” or “assessment” factors that contribute to the final result. An entirely different type of precautionary action is pre-screening. It can be seen as a reaction to the problem of divergent time scales. On the one hand one observes the ever-accelerating pace of technical innovation. On the other hand it can last for decades before adverse effects appear in man or the environment and there may be another decade between a first suspicion and its full scientific confirmation. However, even then it can take considerable time before management measures remove adverse effects of failed innovations. For some humans or species full scientific clarification may come too late. The problem of divergent time scales calls for a kind of precautionary pre-screening that tries to identify cases where immediate reaction is urgent.

With regard to chemicals, one remembers that their presence is a necessary condition for adverse effects. This simple logical fact gives exposure and persistence a special

---

importance: if it turns out, possibly a long time after release, that an apparently inconspicuous persistent compound has negative biological effects, it is impossible to eliminate it from the environment. The resulting situation would be unmanageable because even immediate phasing out may not ameliorate the situation quickly enough for some species. The PCBs and the European Otter (*Lutra lutra*) can be regarded as a typical example of this scenario.

These facts have been used to propose a general approach to environmental precaution by controlling necessary factors of adverse effects instead of controlling risks directly. The approach recognizes the fact that the probability of an adverse effect factorizes into the probability of a chemical being at a given place and the conditional probability for adverse effects, given its presence at said place. In the language of standard chemical assessment one would say that the probability of adverse effects factorizes into exposure and the probability of (toxic) effects at given exposure.

In order to be as specific as possible, however, one has to take into account that longevity alone does not lead to possibly unmanageable situations (see e.g. concrete, bitumen, plastics, etc.). It is only in combination with other controlling necessary factors such as mobility and/or bio-accumulation that persistence is a significant indicator for possible large-scale environmental threats.

Screening out chemicals with high persistence, mobility, or bio-accumulation potential is a type of precautionary pre-screening proposed by several authors. The corresponding parameters can be determined from chemical information alone. In this setting, persistence, mobility, and bio-accumulation potential appear as endpoints of an exposure-based assessment which can be done by chemistry alone, without referring to toxicology or ecotoxicology.

4. A case of type II ambiguity?

The precautionary principle as a management tool is still highly controversial, both in the US and in Europe. Although there are too many pros and cons to be briefly summarized, it can be said that many critical objections come from the risk assessment community: as risk denotes the combination of probability times magnitude of adverse effects, risk assessment in its standard form is necessarily effect-based. This is contrary to exposure-based assessment approaches, such as precautionary pre-screening, which may explain a

---

7U. Müller-Herold: “Measures of Endangerment”, *The Geneva Papers of Risk and Insurance, 80*, 383–392 (1996). In an introductory address the editors write: “Müller-Herold's paper introduces a conceptual alternative to risk analysis as the basis of risk management. Risk denotes the combination of probability times magnitude of adverse effects. Conventional management strategies are designed to reduce either one of the two components. Müller-Herold argues that the precautionary principle in environmental policy making requires an approach that implies management steps at an earlier stage. His target is what he calls "endangerment". Controlling endangerment means controlling the scope and range of the potential for damage. He develops a taxonomy of endangerment that comprises two main factors: spatial extension and persistence over time. These two factors determine the degree of endangerment regardless of their strength of destructive potential.”

8 For a first orientation the reader is referred to a special issue on the precautionary principle of the journal *Human and Ecological Risk Assessment, Vol. 5*, 1999
sometimes far-reaching lack of understanding as well as the calls for so-called “sound
science”, which occasionally appears as synonymous with effect-based assessment. In
this perspective the debate is shaped as a controversy between the mainstream of an
established community and a dissident minority.

With respect to precautionary pre-selection of chemicals, things can be viewed from a
second, largely different, perspective: “exposure-based” means environmental chemistry
and “effect-based” means toxicology. It is notable that the toxicology community is
reluctant with respect to precautionary pre-selection. Evidently, it is not toxicology which
controls the corresponding endpoints. To be clear, exposure assessment is part of
standard chemical assessment, and standard chemical assessment will continue to have
toxicological endpoints and to play its present-day regulatory role for chemicals
surviving a foregoing precautionary selection. The essential difference is the promotion
of exposure to an endpoint in the small and novel field of precautionary pre-screening. In
this perspective, the debate appears as a type II ambiguity between environmental
chemistry and toxicology: will there be a shift in disciplinary leadership or will
toxicology extend its leading role to precautionary pre-screening of chemicals?

For this question it is crucial whether toxicology and ecotoxicology prevail the
overcomplexity problem: is it possible to find novel and sufficiently universal endpoints
allowing for rapid and reliable pre-screening? It seems that the new fields of toxicogenomics,
which looks at gene expression or expression patterns, could open up new
vistas. This would lead to a situation of mixed responsibility for pre-selection. In addition
to exposure-based endpoints, there would be new toxicodynamical endpoints, and
suspicious chemicals might be screened out by either of them.

**Acknowledgment**

The author gratefully recognizes critical remarks by S. Funtowicz pertaining to problems
of ignorance, uncertainty and ambiguity in risk research.