Coping with Contested Knowledge in the Environmental Risk Assessment of Chemicals: Formal Models as Facilitators of Social Learning Processes

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Abstract

Micro-contaminants increasingly become a problem for water resource management in industrialised countries. Present in everyday products like plastic packages, pharmaceuticals or personal care products, they enter waste waters and are meanwhile detected prevalently in rivers in environmentally relevant concentrations. For most of the numerous substances, however, only little is known about their environmental behaviour and impacts. The environmental risk assessment (ERA) of micro-contaminants is challenged by complexity and uncertainty. Uncertain and thus contested (scientific) knowledge however leads to ambiguities with respect to evidence and values or interests. It is the basic assumption of the research project INTAFERE ("Integrated Analysis of Mobile Organic Foreign Substances in Rivers") that the ERA of micro-contaminants therefore has to become the subject of a dedicated societal decision-making process. The research approach is to simulate in "lab-scale" this process as a common learning process among stakeholders and between society and science. A series of workshops with representatives from different sectors of society serves to set up a structured dialogue which is intended to generate consensual and sustainable proposals for adapted ERA procedures. An important instrument within this stakeholder dialogue is a formal model which maps the consequences of the societal handling of micro-contaminants to a concrete region. It basically translates generic data of production and consumption into expected emissions of specific substances into the environment, determines the resulting hydro-chemical and biological state of the surface water in the area under investigation and finally assesses possible impacts for the aquatic environment. The paper presents the overall project concept, results of the ongoing stakeholder dialogue and the modelling concept.

1 Micro-contaminants: A Challenge for Water Resource Management

In recent years water resource management in industrialised countries is challenged by a new class of chemical substances: micro-contaminants. Present in everyday products like plastic packages, pharmaceuticals or personal care products they are meanwhile detected prevalently in rivers in environmentally relevant concentrations. The reason for their ubiquitous occurrence is that in comparison to contaminants like the infamous persistent organic pollutants (POP) micro-contaminants are better water soluble and only poorly degradable by biotic or abiotic processes. An effective elimination of the substances in conventional sewage treatment plants is thus often impossible (cf. Höhne/Püttmann 2006). Once emitted into water bodies micro-contaminants have the potential for long range dispersion and impact on a multitude of aquatic organisms. Ecotoxicological analyses in fact show that certain substances can have biological effects already at

trace levels, i.e. at concentrations of a few billionth of a gram per litre (cf. Oehlmann et al. 2006). However, for most of the numerous substances there are substantial knowledge deficits with regards to their overall environmental behaviour and (long-term) eco-toxicological impacts (cf. Keil/Kluge 2005 and references therein). The assessment of whether or not the hazardous potential of micro-contaminants poses a risk for aquatic ecosystems and the natural water resources is thus a complex task which is prone to fundamental uncertainties.

2 The Role of Knowledge in Environmental Risk Assessment

Risk assessment is the assessment of specific knowledge with regards to hazards created by societal action and possible adverse effects on humans or the environment. The result of an assessment, however, not only depends on scientific evidence but also on values or interests. Both evidence and values can (and usually will) be disputed during risk assessment, leading to conflict and possibly severe decision problems. The International Risk Governance Council (2005) in these cases refers to *interpretative* and *normative ambiguity* of a risk problem. Within a general framework of risk governance one can distinguish two critical phases where ambiguity comes into play:[1] (1) before the actual assessment starts it has to be decided upon the hazard and risk to be considered and the conventions and methods applied to perform the scientific risk analysis; (2) after this analysis the risk has to be characterised and evaluated, i.e. a judgement has to be made on the acceptability or tolerability of the risk. In both phases there is ambiguity with respect to evidence and values.

The ultimate reason for ambiguity is complexity and (the corresponding) uncertainty. The relevant cause-effect chains of a risk problem are, except from simple and thus rare cases, usually hard to establish: a multitude of factors – physical, biological, chemical, social, cultural etc. – may have an influence on whether and how a subject of protection is exposed to a hazard or crucial causal links can be masked by long time delays between the release of a hazard and an adverse effect. Capturing this complexity in models is often incomplete or inadequate leading to different kinds of uncertainties (cf. Brugnach et al.). Now, the more uncertain the specific scientific knowledge is the more it is contested and the more it becomes subject to interest driven interpretations of different societal actors. This situation in particular holds for the environmental risk assessment (ERA) of micro-contaminants.

For illustration consider the current ERA scheme for chemicals of the European Union (EU-ERA). Although it is an advanced and powerful tool proven to effectively minimise risks for the environment it has two important drawbacks. Firstly, it is a single substance approach – the final outcome of an ERA for a specific chemical is a comparison between its predicted environmental concentrations and predicted no effect concentrations (cf. ECB 2003). As such it doesn't take possible effects of mixtures of substances with the same mechanism of action into account (the real world exposition scenario).[2] Secondly, there is growing evidence that in particular certain

1 We relate in this paper to the conventions and terminology of the International Risk Governance Council (2005).

2 Data on effects of substance mixtures is still sparse. Estrogenic effects for mixtures where the composing substances are present at concentrations below their individual thresholds are e.g. documented in Rajapaske et al. (2002).

micro-contaminants show non-monotonous dose-response relations, i.e. they have adverse effects on aquatic organisms at very low concentrations which are not observed at higher doses (cf. Schulte-Oehlmann et al. 2001, vom Saal/Hughes 2005). This observation severely challenges the concept of effect thresholds for individual substances. On the basis of these findings distinctions between harmful and harmless, hazardous and safe become increasingly blurred.

3 Embracing Contested Knowledge: The INTAFERE Approach

The examples illustrated above show that the ERA of micro-contaminants is prone to dispute and conflicts of interest, i.e. it is characterised by and dependant on the acquaintance with contested knowledge. More generally speaking, there is a lack of societal consensus on an appropriate acknowledgement and appraisal of the risk problem: demands and needs for protection are opposed to demands and needs for utilisation, based on differing and sometimes contradictory underlying values. Stakeholder participation in both of the above mentioned phases of risk governance is therefore mandatory in order to address and embrace the corresponding interpretative and normative ambiguities. This procedure is applied by the research project INTAFERE ("Integrated Analysis of Mobile, Organic Foreign Substances in Rivers").[3]

The major goal of INTAFERE is to generate consensual and sustainable proposals for adapted ERA procedures for micro-contaminants. The research approach is to simulate in "lab-scale" the societal decision making process as a common learning process between stakeholders and between society and science. An important feature of such an approach would be that it encompasses the complexity and uncertainty of the risk problem in order to make it accessible for the decision process. This goal implies tackling different tasks: INTAFERE aims at improving and evaluating the existing scientific knowledge base about micro-contaminants and their impacts on aquatic organisms. This is achieved by monitoring surface waters in a dedicated reference area and analyses of representative micro-contaminants and their eco-toxicological impacts. Beyond that an integrative perspective is needed, which captures the societal drivers of the risk problem. Therefore the results of ecological analyses and studies of material flows are linked with social and economic activities via scenario development and integrative modelling. The modelling approach is described in the following section. Its purpose is the transformation of conflicts of interest in cognitive operations.

Stakeholder participation in INTAFERE is organised as a structured dialogue among key actors from chemical industry, water management, public authorities, civil society and science. It consists of a series of four one-day workshops with the following thematic foci: (1) perspectives on procedures and results of ERA, (2) scenarios of future developments of the risk problem, (3) revision of perspectives on ERA and, (4) options for risk management. Participatory methods used comprise moderated discourse, development of scenarios in working groups and the use of the

[3] The project uses the term "mobile, organic foreign substances" instead of "micro-contaminants", since it better reflects the intrinsic properties of the substances in question. The term micro-contaminants, however, is more frequent in the public debate and thus used here. For a detailed project description please visit www.intafere.de.

integrated qualitative-quantitative model as a facilitator for a learning process on consequences of conflicting interests and decisions under uncertainty.

The first workshop on "Perspectives on procedures and results of ERA" took place in January 2006. An important result of the workshop was that the main propositions on ERA introduced by the project team as a starting point for the plenary discussion were shared by the stakeholders. In particular there was principal agreement that the single substance approach of the EU-ERA has to be supplemented by procedures that account for possible effects of substance mixtures. It was, however, noted that a renunciation from the single substance approach may lead to dispute about problem ownership. A suggestion to overcome this dilemma was to introduce an assessment criterion "potential for additive effects" to a single substance based on its specific mechanism of action (provided the evidence that this mechanism is likely to exhibit additive effects in substance mixtures). In addition it was agreed upon that, given the complexity of the risk problem, uncertainty has to be addressed more explicitly in ERAs. It was however stressed that with respect to both aspects new procedures should be kept simple in order not to overload the already highly elaborate EU-ERA. A strengthening of the precautionary principle was therefore seen as the most promising strategy. Overall the stakeholders appreciated a strong participatory approach in risk assessment. They considered the projects stakeholder dialogue as a unique opportunity to frankly discuss controversial issues.[4] The second workshop is scheduled for October 2006.

4 Coping with Contested Knowledge: A Formal Model for Social Learning

How can risk problems which are characterised by contested knowledge be made accessible for the research process? As mentioned in the preceding section, the participatory development of scenarios in INTAFERE serves as an instrument for mapping conflicts of interests to cognitive operations in order to facilitate a successful process of negotiation. It aims to collect the diversity of stakeholder perspectives in order to open them for learning and discussion beyond the individual limits by *playing* with possible future scenarios and estimating their implications. In consequence they can strengthen the mutual understanding of the various stakeholders' positions and ideally support the formulation of a consensus about acceptable conditions for sustainable paths into the future. For embedding this participatory scenario development in a scientific process, further systematisation has to be conducted in order to facilitate the application of scientific methods. To meet such a systematisation the relevant interactions among stakeholders and subsequently between society and nature have to be analysed and transformed by an appropriate formalisation into suitable scientific objects of investigation. This results in formal, integrated models describing the context of contested knowledge and opening it to analytical methods of the scientific disciplines involved. Furthermore, formal models complement the scenario development as a tool which ensures transparency and consistency of the process.

Environmental risk assessment is affected by constellations of societal and ecological problems which lead to particular requirements in formalisation. Formal models in this context have to describe phenomena in both dimensions as well as in the dimension of their interactions. The ap-

[4] The authors will provide a detailed summary of the first INTAFERE stakeholder workshop on request.

proach of the INTAFERE project reflects this circumstance by building a threefold structure of societal, natural and cross-cutting components into the formal, qualitative-quantitative model.

The societal component aims to describe the relevant mechanisms of the stakeholders' actions and interactions. The objective is a better understanding of these mechanisms and a better estimation of future options for action as well as the revelation of dependencies of future decisions. Even if the specific contexts of stakeholders are different and their decisions are based rather on subjective than on objective views of the problem, the mechanisms and relations between their perceptions, goals, prospects, external factors and options for action exhibit a high degree of generality. This insight is the conceptual basis for the software tool DANA (Dynamic Actor Network Analysis) which was developed at Delft University for the support of policy analysts (Bots et al. 2000). DANA is being further developed in cooperation with the project INTAFERE for an adaptation to the specific requirements of the project. The first step in the formalisation of the societal component is the qualitative formulation of perception graphs for each stakeholder based on expert interviews. Out of these expert interviews the characteristics of the different subjective perceptions are filtered, translated into the framework of DANA and analysed. The second step is the connection of all individual perception graphs into *one* joined network of perception graphs – the *actor model*. Finally, the temporal evolution of this joined network is planned to be simulated in the third step by several well-defined interaction processes between the different perception graphs of the stakeholders.[5] The intention is the simulation of actions in parallel to the participatory development of scenarios, thus providing a more profound basis for an estimation of their future impacts on the risk problem (e.g. trends in the production and consumption of selected micro-contaminants).

The ecological component of the formal model aims to quantitatively describe pressures on the state and exposure of water bodies as a consequence of emissions of micro-contaminants. For concretisation INTAFERE focuses on the Hessian Ried, a region of major importance for the drinking water supply of the Rhine-Main urban agglomeration. This so-called *regional model* is calibrated by the empirical results of a three-year hydro-chemical measurement campaign at 26 sites on all watercourses of the region[6] and comprehensive eco-toxicological analyses. It comprises structural elements of the surface water bodies relevant for the estimation of the expected spatial distribution of emissions of micro-contaminants and the identification of potential hot spots concerning the exposure of aquatic organisms with micro-contaminants.

The cross-cutting component aims to connect the societal to the ecological component in order to translate the consequences of the actor model to an input into the regional model. More precisely, this means an estimation of environmental emissions depending on changes in production and consumption as a consequence of changes in the stakeholders' actions, behaviours and regulatory procedures. A crucial role in performing this task is the software EUSES (European Union System for the Evaluation of Substances, 2005). This tool was developed on behalf of the European Commission in order to support decision-making in the assessment of old and new sub-

5 For a detailed description of the use of DANA in INTAFERE see Döll and Döll (2006).

6 Parts of the results are documented in Quednow and Püttmann (submitted).

stances. It is based on ECB (2003) and facilitates an efficient and appropriate way for translating trends of production and consumption into expected emissions of specific chemicals into the environment.

The formal model with its different components covers a wide spectrum of scales from overall positions and actions of societal actors down to regional and local ecological consequences. It has to be viewed as an important tool for achieving transparency about the fundamental backgrounds of decisions and actions, for the confrontation of stakeholders with possible corridors of consequences of actions and for the creation of suitable conditions for a common consideration about the criteria for acceptability of possible future scenarios.

5 Conclusions

The present experiences of INTAFERE have shown that the organisation of a structured stakeholder dialogue is a promising approach to embrace and to cope with contested knowledge in the environmental risk assessment of micro-contaminants. The use of a formal model as a facilitator for a social learning process indeed always means making an in itself contestable and probably inadequate reduction of the real risk problem at hand. However, it has the unique potential to generate insights into the complexity of the major cause-effect chains at stake. To which extent the formal model supports the problem specific learning process will only turn out after the INTAFERE stakeholder dialogue is completed.

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