Risk is a Construct

Perceptions of Risk Perception

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Risk Management by Setting Environmental Standards

Summary

If environmental immissions place human health and well-being at risk, it is the responsibility of the authorities to assess the scientific knowledge available in order to identify critical exposures and to initiate appropriate abatement measures which protect the affected population. Such measures are typically the setting of emission or immission limits, i.e. environmental standards. However, the utilization of scientific research for the purposes of risk assessment and political decision-making leads to manifold problems. Cardinal difficulties are that the effects of environmental stressors constitute a multicausal process; that data on somatic, psychological or social effects and related evaluations of unacceptable impacts have to be converted into physical and/or chemical units; and that normative statements (not just empirical findings) are required. From this it follows that the make-up of the decision-making body and its legitimation are of key importance, over and above the data basis used and the underlying risk model. Moreover, efficacy studies are required to determine to what extent the defined standards actually bring about the intended protection, in other words whether they are an effective risk management tool.

Foreword

This chapter will look at a particular problem of dealing with risk, that is how to convert knowledge about hazards into exposure limits (German: "Grenzwerte") protecting the affected population. This relates to the issue of "Risk is a Construct" in two different respects: firstly, most of the hazards in question are of a probabilistic nature, in other words, it is not certain that their feared effects will actually occur; secondly, the establishment of critical exposure limits is far more a societal than a scientific or technological issue. How society perceives and evaluates risks to the community at large and/or to the individual obviously has a crucial impact on the way these risks are managed – in the present context by setting environmental standards.

1. Environmental Stressors as Risks to Human Health and Well-being

The environment is the habitat which humans endeavour to shape according to their own ideas and in which they pursue a wide variety of activities. However, the structural, physico-chemical and social environment also houses many "environmental stressors", i.e. adverse environmental conditions which may affect people's physical, psychological and social well-being (Campbell 1983, Evans 1983), and which therefore constitute a risk to human health. A list of such factors is given in Table 1.

These factors take effect both at the workplace and in the private home environment. However, the effects are not certain to occur or will not affect everyone exposed, and they may vary considerably in severity between individuals – it is exactly this which makes environmental impacts into risks. It should be noted though that formal risk definitions which are common in risk

Table I

Environmental Problems: Examples	
State of the natural environment	*Hazards for humans*
Soil pollution	Air pollution
Water pollution	Noise
Consumption of natural landscape	Radiation
Waste dumping	Vibrations
Forest dieback	Odours
Erosion/desertification	Heat/cold
Over-use of resources	Food additives
Extinction of animal species	Harmful drugs/cosmetics
Climatic changes	etc.
etc.	

analyses within engineering or insurance issues (such as the product of probability and severity of damage) are hardly appropriate for risks to human health and well-being – a point that has been stressed among others by the Council of Environmental Experts (SRU) in Germany (cf. SRU, 1987, Section 3.1.2).

So far risks to humans and their activities have been mentioned, but it is equally important to consider risks for the environment itself (soil, air, water etc.), including global and long-term hazards threatening the planet and humankind as a whole, such as the much-feared climatic changes. Of course, any deterioration of environmental quality in turn will have an impact on the living conditions of humans.

2. Types of Protective Standards

Generally speaking, there are three ways in which environmental stressors and their effects can be mitigated. These involve:

- changes at the *source of the emission*, i.e. the "emittent" (e.g. measures to prevent or reduce the generation or discharge of emissions; spatial or temporal restrictions of industrial operations; emission limits);
- changes at the *point of immission* (e.g. wearing of protective clothing; structural/engineered safeguards for exposed workplaces and/or homes; immission limits);
- changes in between by increasing the distance or establishing *barriers* between the emission source and the exposed people (e.g. re-siting of production facilities; re-routing of transport movements; relocation of affected communities; construction of protection walls etc.).

Regulators can employ technological and administrative approaches. Basically, these can be understood as instruments of *risk management*. Irrespective of whether the requirements are defined in terms of emissions or immissions, the "target of protection" is always human health. This reflects the "anthropo-

centric" perspective; but, of course, environmental problems may also be considered in terms of their effects on nature – i.e. on fauna, flora, the soil, rivers, lakes, the sea, the atmosphere etc. – and thereby from an "ecocentric" viewpoint. However, dealing with environmental impacts in the sense of ecological risks would be beyond the scope of this essay.

In the following the focus will be on the issue of *limits/standards for environmental factors* which, according to the Council of Environmental Experts "are at the heart of all endeavours to protect the environment" (SRU, 1987, p. 45). The purpose of limits is to mitigate the output or the impact of environmental stressors such that any impairment they cause remains below levels evaluated as "critical", "relevant", "harmful", "unacceptable"; violation of these standards has legal implications (Dekoning 1987, Feldhaus 1979, Salzwedel 1987, Verein Deutscher Ingenieure 1990, Winter 1986b).

The concept of setting limits originated in the field of medicine (or more precisely, in pharmacology and industrial hygiene, cf. Milles & Müller 1986), and was utilized as an administrative tool in the context of industrial health and safety regulations, plant licensing procedures, and accident prevention (Winter 1986b). Extensive efforts regarding human health care, environmental protection and quality of life lead to a multitude of limits for virtually all types of substances and energy sources to which people are exposed and which possibly have a – direct or indirect – impact on human health: dioxin in the soil, atmospheric ozone, phosphates in water, radiation, noise, vibration, formaldehyde in paints, nitrates in food are just a few examples.

However, there are considerable differences in the purpose and legal status of limits. This is manifest in the existence of various modifying or attenuating terms, e.g. "recommended levels", "planning levels" "desirable levels", "target levels", "intervention levels", "acceptable levels". (A good example is provided by the large number of laws, regulations, norms etc. in the field of noise control, governing for instance noise from aircraft, motor vehicles, railways, machinery, and commercial/industrial premises, on either federal, state or community level.) The term "environmental standards" might be seen as the most general notion (Dekoning 1987, Salzwedel 1987).

In the context of risk prevention and reduction, the implementation of standards is geared towards two cardinal objectives: firstly to *avert immediate hazards*, and secondly as precautionary measures in accordance with the *principle of prophylaxis*. Thus, standards can be seen as protective standards (e.g. requirements to control risks to human health) or as prophylactic standards (e.g. limits for the release of specific pollutants from industrial plants); in the case of prophylactic limits a distinction is made between standards for general and for individual protection (see

SRU 1987, Section 1.3; Salzwedel 1987). In their less mandatory forms, e.g. as guidelines, standards serve as planning recommendations or are used by public authorities as decision-making aids in the assessment of specific hazardous facilities or processes. Such applications naturally involve considerable scope for discretion.

Emission and immission limits must be defined in terms of physical, chemical, biological or similar parameters relating to the hazardous medium. In other words, they are expressed in units of the source parameter (the dose) and not of the impact parameter (i.e. the effect).

The following discussion will focus on standards for residential areas and workplaces, i.e. immission limits.

3. Substantive and Formal Criteria for Environmental Standards

As part of their responsibility for the safety and welfare of their citizens, governmental authorities must evaluate the available scientific knowledge about dangers to health and well-being with respect to critical and socially unacceptable risks. They must then establish appropriate measures to protect the exposed population, in particular by setting and controlling environmental standards.

The principal criterion of all protective measures, human *health*, is defined diversely: in a narrow sense as the absence of disease, and in a wider sense as "a state of complete physical, mental and social *well-being*", as expressed in the founding articles of the World Health Organisation (WHO 1946).

The legal objective is to prevent "hazards, significant detriments and significant nuisances", a trio of concepts which is to be found in all relevant German legislation – including the 1974 Federal German Pollution Control Act. Based on the idea of a sound physiological balance, excessive somatic strain is interpreted as a hazard, and excessive psychological and social strain is interpreted as a significant nuisance. The term detriment is used both for economic and social effects.

Obviously, these criteria overlap, and both scientific and political evaluations are required for their fulfilment (Feldhaus 1979, Gross 1980, Nicklisch 1988, SRU 1987 [Chapter 3.1], Rohrmann 1984a [Chapter 5], Vogel 1980, Winter 1986b). As the SRU puts it, environmental standards require two – rather interrelated – assessments: a "protection requirement profile" must be drawn up which assesses the needs of those exposed to an adverse immission and a "hazard profile", which assesses the risk potential of the environmental impact in question.

There is also an economic perspective to the setting of standards: the state can use standards to determine the extent to which it is prepared to accept financial responsibility for the risks of environmental pollution (the community-pays versus the polluter-pays principle). Furthermore, the allocation of risk is linked with insurance and insurability questions (cf. e.g. Siebert

1989). However, this topic falls outside the scope of the present work.

The fundamental basis is provided by the body of knowledge obtained from research in the human sciences (medicine, toxicology, psychology, social sciences, etc.), filtered on the basis of legal provisos. Beyond scientific aspects, however, standards must also satisfy *pragmatic* requirements: they must be unambiguously defined, able to be differentiated (regarding impact magnitudes), administratively feasible, enforceable, and sufficiently strict to fulfil the intended protective function.

The actual setting of the standards is determined not only by the specific features of the hazard in question but also by financial and technical considerations: the scope for decision-making is often constrained by fundamental conflicts between economic, political, ecological, technological and other interests; therefore, "generic" objectives of health protection might not easily win through.

4. Information Required for Setting Immission Standards

Five basic questions must be addressed in any attempt to define, substantiate and implement the "critical" exposure levels or (un)acceptability thresholds, that is to make risks describable and amenable to prevention through standards. These are identified in Table 2 (based on Rohrmann 1988) as follows: the effects issue, the causality issue, the relevance issue, the transformation issue and the regulation issue.

Each of these questions involves specific substantive and methodological problems. This applies to gaining knowledge as well to interpreting and applying it. (Majone 1982, Rohrmann 1984a, 1988, Salter et al. 1988, Vogel 1980, Werbik & Kaiser 1984). It is an interdisciplinary task for research and environmental policy, a problem in which social sciences expertise plays a major role.

5. Example No. 1: Noise Pollution

To illustrate the complexity of establishing immission limits, the case of noise may serve as an example - an almost ubiquitous environmental stressor which has long been the target of abatement efforts.

In Germany, at least half the population is affected by noise (SRU 1987, Federal Environmental Agency 1989). Road traffic is the main cause of noise but aircraft, railways, shipping, industrial plants, construction sites and various leisure activities (e.g. home renovations and woodwork, loud music in discos and from walkmen) are also major sources. Many of them constitute a stressor not only for other people but also for the originators themselves. For those exposed, whether at work or at home, this noise pollution is associated with a wide range of risks: depending on the level of exposure and individual disposition, noise can cause serious disturbances of communication, work performance, relaxation and sleep; impairments of physiological and biochemical functions; and also (irreversible) loss of hearing (see Berglund et

Table 2

Setting of standards: required information	
(1) The effects issue What somatic/psychological/social impairments (B) occur?	B = ?
(2) The causality issue Is the immission (A) a primary cause of the observed effects?	B = f (A)?
(3) The relevance issue Which effects are to be evaluated as undesirable/unacceptable?	B_{crit} = ?
(4) The transformation issue Which levels of exposure correspond to these critical effects?	A:B_{crit} = ?
(5) The regulation issue Which technical and/or regulatory actions provide the desired protection?	τ u/o § = ?

al. 1988, Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen [i.e. interdisciplinary study group on the effects of noise] 1990, Rohrmann 1984a).

Numerous standards (norms, recommendations, laws) for noise control have been adopted in order to reduce those risks (for details cf. Gummlich 1989, Kutscheidt 1989, Umweltbundesamt [German Federal Environmental Agency] 1989). These standards may be characterized as follows:

- they are issued in respect of specific types of noise (road traffic, aircraft etc.), not noise as a whole;
- they are defined in specific acoustic units (in fact a vast diversity of indices has emerged);
- they are usually expressed in terms of a "single-value criterion" which integrates intensity, frequency/duration etc. of the noise exposure into a single index (mostly the mean equivalent sound level L_{eq});
- they (usually) do not consider different types of impacts (e.g. communication, physiological functions etc.), but are based on a global evaluation of effects;
- however, different times of day are usually taken into account through weightings;
- they are often differentiated according to the utilization of the exposed area (e.g. industrial facilities or residential housing) or the type of workplace.

Obviously, standards are based on more than just acoustic information. In consequence, immissions for different types of noise are not directly comparable.

6. Foundation of Standards: Social Science Aspects

In the following, the five issues listed in Table 2 shall be elaborated.

6.1 Identification of Health Risks

To begin with, it is necessary to identify the risks to human health and well-being: i.e. what somatic, psychological, social and economic impairments occur with what intensity and probability? What impacts can be expected to develop?

It is not easy to evaluate the actual knowledge about the impacts of the various environmental stressors. On the one hand, there is a huge number of studies available (the environmental report published by the SRU in 1987 provides a very comprehensive treatise). On the other hand, however, there are many issues that are not yet understood very well, for instance the cumulative and long-term effects of environmental stressors, their influence on social processes, impacts on specific population groups (e.g. children), or differences in effects between long-standing and new/recent environmental stressors.

Such lack of knowledge is true for each specific environmental factor (for the areas referred to in this text, noise and chemical hazards, cf. e.g. Rohrmann 1984a, Uth 1990). Furthermore, the body of research findings available on combined risks (such as noise plus air pollution, or chemical immissions plus radiation), is far less comprehensive, especially as potential synergic effects are much more difficult to analyze.

6.2 The Question of Causality

Impairments justify the imposition of immission limits only if the environmental stressor is proven to be a significant causal factor, i.e. if it is possible to describe the "effect path" of the risk. However, the impact of stressors cannot be seen as a simple stimulus-response relationship (or as physically determined, see Franck 1984). Rather, a multicausal process is to be assumed (cf. eg. Rohrmann 1990): the extent to which somatic, psychological and social impairments result from the exposure to the environmental stressor will depend intimately on the personal characteristics of the affected individual and on the situational context of the impact.

Accordingly, empirical data reveal only moderate correlations between the degree of exposure (A) and the degree of impairment (B). For example, field studies on the effects of noise, vibration or air pollution usually revealed correlations r(AB) between .10 and at most .60 (in statistical terms this means that at best ⅓ of the variability of the "response" can be attributed to the "stimulus"). Moreover, codeterminating factors ("moderators") also play a considerable part, as already mentioned; such moderators include personality traits, in particularly stressor-related dispositions and attitudes, general state of health, and situational circumstances, i.e. when, where and in which social context the environmental stressor intrudes. This means that (A) is only a partial cause of (B), or that changes in (A) will affect (B) only on a probabilistic base.

Even if the mean effect of a particular environmental impact can be assessed (on the basis of aggregated data), it is still not possible to determine the risk to a given person – because of the wide variation of reactions between individuals within the same exposure level.

6.3 Appraisal of Relevance

Impairments must be assessed in terms of relevance. This is the key problem particularly in the context of psycho-social effects – "nuisances" in legal terminology – since only *significant* nuisances are relevant under law – at least within the German pollution control legislation. But what constitutes "significance" (German: "Erheblichkeit")? Rohrmann (1984b) discusses the following criteria: intensity, frequency, reversibility, avoidability and compensability of effects. Such criteria must be applied to all affected areas of human behaviour; moreover, these areas need to be weighted in relation to each other. Appraisals of this kind must reflect the experiences of the affected individuals and must therefore be validated by subjective data. (That leads straight into the debate about "objective" risk definitions versus "subjective" risk perception).

If an impairment is not (yet) considered to be "significant", the stressor and the risk associated with it are supposed to be "reasonably acceptable". The concept of reasonable acceptability (German: "Zumutbarkeit", cf. e.g. Feldhaus 1979, Kutscheid 1982) can be related to the concept of "acceptable risk" (cf. Fischhoff et al. 1982), or at least to interpretations that certain risks are to be tolerated by society (though moderated by a deliberation process).

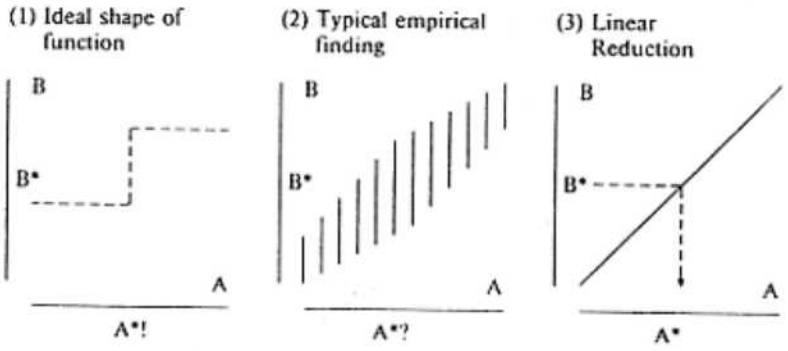
It is obvious, however, that the distinction between significant and non-significant impairment levels is ultimately a normative problem (Dekoning 1987, Majone 1982, Rorhmann 1984a, Winter 1986a). Moreover, nearly all environmental effects increase gradually rather than exhibiting any abrupt qualitative change across exposure levels, and this makes the assessment problem even more difficult. In addition, different people evaluate different effect levels as "significant" impacts.

It is also important to remember that society's demands regarding environmental quality, hazard abatement and safety are not static – nor, indeed, is the state of the art of technologies; instead, they are subject to change (usually becoming more stringent but also lessening in times of economic constraint). Actually, the perception and evaluation of risks are always subjective processes and are to a large extent determined by concomitant sociocultural influences (Douglas & Wildavsky 1982, Jungermann & Slovic 1991, Rohrmann 1991; cf. also the chapters on cultural factors in this present book).

All (un)acceptability limits are substantiated by impairment scales (B), but the associated technical and/or legal regulations are always defined and implemented in terms of physical stressor

Figure 1:

Impact functions



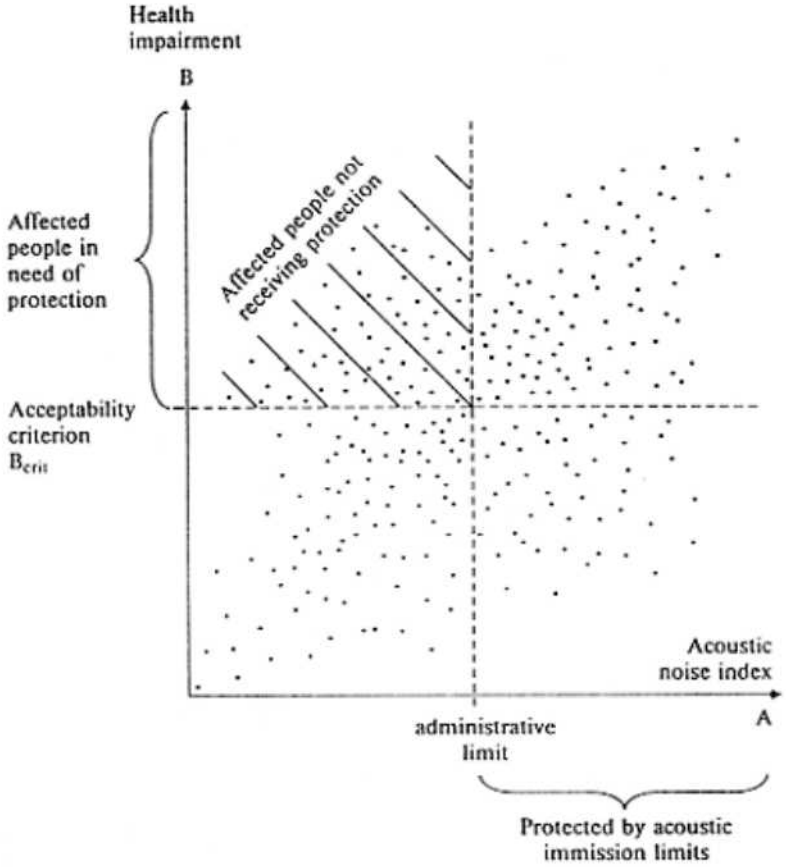
A = Degree of exposure (physical stressor scale)
B = Degree of impairment (social-scientific response)

scales (A). Evaluative statements within (B) must thus be converted by means of a suitable function into terms of (A). In principle, this transformation is performed on the *basis of dose-effect curves* or "risk functions". These depict data on (B) as a statistical function of (A) and are intended to express, for example, the probability of certain detrimental effects at each exposure level (Beyersmann 1986, Dekoning 1987, Grimme et al. 1986, Wagner 1990). In dealing with psychological and social effects, Rohrmann (1984a) refers to "impact functions". It is in this area that the transformation problem is particularly difficult: to relate an exposure limit "A*" to a critical impairment "B*" is relatively straightforward only if there is a "step function" (see Figure 1, Case 1); in reality, however, empirical data generally yield Case (2), which, at best, can be reduced on a statistical basis to yield a linear solution as in Case (3).

Such functions for representing the relationship between exposure and effect(s) are the result of more-or-less arbitrary methodological decisions regarding the statistical rationale, the risk concept, and the criterion variables to be used for A and B (and may actually be subject to manipulation). The determination of thresholds (see also Section 7) and the extrapolation of the respective data at the lower end of response scales are the most difficult tasks. Moreover, the available data on practically all types of environmental impact are quite heterogeneous – therefore cogent

Figure 2:

Validity of noise immission limits



solutions are hard to determine. (For an in-depth discussion see Winter 1986a, Chapter I; cf. also Rohrmann 1984a, Chapters 4 and 5.)

6.5 Effectiveness of Regulation

The prescription of environmental standards is nevertheless necessary and definitely feasible. Standards should be substantiated by medical and/or social science data; they should provide effective protection for people at risk; and it should be possible to verify their effectiveness (cf. the criteria cited earlier: soundness, strictness, ability to discriminate, unambiguity and feasibility).

Actual immission standards - for example those established in the German aircraft noise control legislation (FlSchG 1971) - achieve these aims moderately, mainly because the (A)-(B) relation is embedded in such a complex structure of effects. Figure 2 is an attempt to illustrate the - inevitable - inadequacy of these standards.

The less the physical/chemical and/or administrative/legal definition of a standard correlates with the medically or psychologically critical impact threshold, the larger will be the fraction of the affected population left virtually unprotected.

Standards are defined (both on the stimulus and on the response side) on the basis of average conditions and are intended to generalize across specific situations and individual risk characteristics. Although this enhances their universal validity, it at the same time reduces their effectiveness in respect of individual cases, because the variability of responses is ignored. Only even stricter limits can compensate for this effect.

There is another disturbing drawback of regulation by standards. Although limits are meant as bans, they might implicitly be interpreted as an allowance, (i.e. almost a licence to pollute): emitters are free to produce noise or to discharge chemical pollutants into the air, the water or the soil up to the limit, or they can neglect to implement feasible reductions in emissions. Used as regulatory tools, therefore, standards can be counterproductive to the aim of risk control if they are administered too statically.

Another kind of problem inherent in the use of standards as regulatory tools is that the risks to be controlled are becoming more and more global – for example, the world-wide proliferation of pesticides or impending climatic changes induced by atmospheric pollutants (e.g. CFCs) – while standards are usually the outcome of national decisions that can be enforced only within a country's boundaries. Thus global effectiveness is extremely difficult to achieve.

7. Example No. 2: Chemical Plants and Products

The problems involved in establishing and justifying standards are even more complex where the chemical industry is concerned, even if only because of the sheer diversity of chemical substances and their conceivable effects.

It is estimated that (for Germany) there are around 70,000 substances in use and that 5–10% of these are potentially hazardous, with a distinction being made between toxic hazards and hazards due to fire or explosion (Uth 1990).

These risks relate to human health, the condition of the natural environment (soil, water, air as well as fauna and flora), and to the state of materials (e.g. buildings). Hazardous immissions may result from the operation of chemical plants (of which there are several tens of thousands in Germany), from the transportation of chemicals (by road, rail, water or air), from the use of chemical products (e.g. fertilizers, medicines, cosmetics/sanitary products, paints etc.) by consumers, and from the disposal of wastes and hazardous substances. The various risks are by no means only the result of accidents but can also evolve during "normal operation". (For more detailed information on this topic, see the sections of

the 1987 SRU report which deal specifically with chemicals; cf. also UBA 1990.)

The fact that chemical plants and products are so salient in the public's risk perception was very much induced by a number of appalling accidents, for example Seveso, Bhopal, Basle, Herborn etc. (Kleindorfer & Kunreuther 1987). Chemical hazards are also associated with a number of particularly dreaded diseases, with cancer naturally heading the list. Recently, the waste incineration issue has aroused intensive (and for the most part negative) public reaction (cf. e.g. Wiedemann et al. 1991b). Moreover, chemical emissions and products play a major role in cross-border and even global risks, as there are no barriers to prevent the world-wide dispersal of pesticides, fluorohydrocarbons, phosphates, antibiotics etc. The fact that many of these substances are extremely long-lived naturally increases their hazard potential even further.

A wide range of *risk management* instruments has been implemented to deal with these chemical hazards. The legal basis in Germany is provided by the 1974 Pollution Control Act (BImSchG), the Hazardous Substances Decree of 1986 under the Chemicals Act, the 1988 Accident Control Decree, the Food and Consumer Goods Act, and numerous special-purpose laws, decrees (e.g. the air pollution control code "TA Luft"), technical standards issued by DIN or the German engineers' association VDI etc. (see overview in Uth 1990). Federal, state and local regulations variously apply, depending on the hazard potential of the specific case; for example, around 5000 industrial facilities in Germany are currently subject to the provisions of the Accident Control Decree. Essentially, three regulatory instruments are employed:

- operating licences/restrictions;
- technical safety requirements;
- standards, i.e. emission and immission limits.

Standards play a cardinal role in the management of chemical risks. Very large numbers of such limits have been imposed, dealing with the operation of chemical installations and the composition of chemical products as well as with the environmental "media" which may be exposed to the hazardous effects of chemicals, i.e. water, soil and air (including effluent discharges, waste disposal, intrusive odours etc); cf. Kleindorfer & Kunreuther 1987, Otway & Peltu 1985, SRU 1987, UBA 1987 and also the reviews in VDI 1990). However, far more standards have been issued to regulate chemical emissions than immissions (Uth 1990), partly because of a preventive perspective and partly because of the difficulties involved in substantiating and effectively monitoring critical exposure limits for the affected population.

The methodological principles of *setting standards* evolved primarily in the fields of pharmacology, toxicology and epidemiol-

ogy (Beyersmann 1986, Bollschmiter 1990, Eimeren et al. 1987, Grimme et al. 1986, SRU 1987). The major concepts used to define *critical levels* of immissions/pollutants include:

- ADI = acceptable daily intake;
- NOEL = no observed effect level (detection threshold);
- LOAEL = lowest observed adverse effect level;
- MAK = maximum allowable (workplace) concentration [German: "Maximale Arbeitsplatzkonzentration"]
- BAT = biological tolerance level for substances at work [German: "Biologische Arbeitsstoff-Toleranzwerte"]

Safety factors or uncertainty margins are sometimes applied (usually factors between 1 and 10) to shift the immission limits towards lower values.

Numerous federal and state authorities as well as scientific and technological committees are involved in the specification of such standards and guidelines.

The adequacy of protective standards is crucially dependent on how well the effects of the respective chemical pollutants on the population - whether at work, at home or elsewhere - are known, and how effectively they are converted into rigorous limits. This is complicated by a number of facts:

- risk studies on chemical substances are mainly based on animal experiments; their validity for humans is restricted;
- many chemical risks relate to malfunctions or accidents; these are in principle infrequent events which cannot readily be "extrapolated" into dose/effect or risk functions;
- limits are usually formulated with regard to a healthy population of working age (and might therefore be inadequate for other specific populations);
- psychological and social consequences must be considered in addition to detrimental somatic effects, but are harder to define and quantify;
- very many of chemical substances or compounds have not (yet) been adequately researched;
- the chemical industry and the widespread use of chemical products are economically so important that it is not easy to push through "tough" regulations.

Nevertheless, a vast fund of findings is available from biological, medical and (some) social science research into the effects of pollutants (summarized in the 1987 SRU document; see also UBA 1987 and the overview in Uth 1990.)

During the last decade the many problems encountered in controlling chemical risks by means of standards have induced a momentous and ongoing political debate on the chemical industry (Held 1988, Hoechst 1989). At the same time chemical emission regulations met with particularly harsh criticism (cf. e.g. Kortenkamp et al. 1988, Böhm 1991), both as a matter of principle and on a case-to-case basis.

8. Institutions Responsible for Standard Setting

The discussion so far reveals that it is virtually impossible to identify standards such as critical levels of environmental stressors simply by the application of empirical research. Instead, standards are established on the basis of social and political considerations, which are naturally quite dependent on the value system held by those involved in the decision-making process. Like any risk evaluation, the setting of standards is a *normative* act, which results from a complex weighing-up of benefits, risks and costs. Consequently it is crucial how the bodies responsible for setting standards are defined and constituted, and which opportunities the affected social groups have to articulate their interests and to influence impending environmental policy decisions (Majone 1982, Rohrmann 1984a, Winter 1986a; see also Edwards & von Winterfeldt 1987). Even if the formal powers of decision rest with the state, it is imperative that those affected by the decision *participate* in the process. In Germany as elsewhere, a complex and elaborate system of cooperation between legislative and executive bodies, scientific institutions, and interest groups has developed to this end.

Still, there is a growing demand to better represent the plurality of interests, to give the decision-making bodies a broader legitimation, and to accept the "lay" public as participants in the process of standard-setting (Winter 1986a, Chapter I). Innovative approaches to this are discussed e.g. in Dienel 1978, DiMento 1986, O'Riordan 1988, Vlek and Cvetkovich 1989, Wiedemann, Femers & Hennen 1991.

The fact that the information rights of citizens have gradually been extended in recent years (e.g. as a result of the "Seveso directive"; cf. Baram 1984, Uth 1990) may accelerate political changes in this direction.

As for the role of *science* in the standard-setting process, it is obvious that "critical" exposure limits and the underlying dose-effect functions cannot be identified positively. For this and other reasons (see Kortenkamp et al. 1988, Winter 1986), the concept of environmental standards has become increasingly controversial. Moreover: as Irle points out (1974), taking up a thought by Max Weber, scientists can only tell us what we can do, perhaps also what we could want to do, but not what we should do.

Research into environmental stressors and the associated risks to exposed populations is also needed to guide environmental policy decisions. The more accurately researchers reflect on the validity of their findings and the more they strive to bridge the – often considerable – communication gaps between scientific institutions, governmental authorities, and the public (DiMento 1981, Salter et al. 1988, Salzwedel 1987), the better they can assist the necessary decision-making.

Actually, the findings and decisions upon which standards are based often lack transparency and are barely intelligible to the

general public. Thus, explaining the concepts and data underlying regulations such as environmental standards can be seen as an important task within the field of "risk communication" (see Covello et al. 1986, Jungermann et al. 1988, 1990, Krimsky & Plough 1988).

9. Evaluating the Effectiveness of Standards for Risk Management

Given the difficulties in defining effective standards, systematic evaluation research is equally indispensable (cf. Patton 1986, Rossi & Freeman 1985, Wottawa & Thierau 1989 for the pertinent methodology). Careful analysis and interpretation are required to determine whether the employed standards actually bring about the desired protection against impairments of health and well-being.

With reference to the criteria discussed in Section 3, the following questions should be addressed:

- Is it sufficiently defined which stressor levels exceed the standard?
- Does the criterion on which the standard is based allow a valid discrimination between strongly and less strongly affected individuals?
- What fraction of the population exposed to the particular risk lies above and below the immission limit, i.e. to what extent is the protection mechanism sufficient?
- Is the responsible authority able to implement, monitor and verify the standard?
- To what extent do the emitters comply with or violate the emission/immission limits?
- What are the financial implications for those affected by environmental standards?
- To what extent are the standards accepted by those at risk, i.e. do they fulfil their social function as risk management tools?

Social science evaluation studies are costly but indispensable for controlling and improving the setting and administration of standards.

Both theoretical discussions about the concept of standards and empirical research into the efficacy of regulations (Kortenkamp et al. 1988, Kutscheidt 1990, Rohrmann 1988, Salzwedel 1987, Vogel 1980, Winter 1988a) elucidate the limitations of this approach to managing risks. Indeed, the imposition of standards is only one - and on its own certainly insufficient - method of averting hazards and preventing risks. It is, of course, much easier to question "the limitations of the critical-limits approach" than to find practicable alternatives - which is all the more reason for both scientists and politicians to develop environmental standards into an efficient means of risk management.

Bibliography:

Baram, M. 1984: "The right to know and the duty to disclose hazard information". *American Journal of Public Health*, 74, 385-390.

Berglund, B., Berglund U., Karlsson: J. & Lindvall, T. 1988. *Noise as a public health problem* (5th Congress, Proceedings). Stockholm: Swedish Council for Building Research.

Beyersmann, D. 1986: "Einige biologisch-chemische Grundbegriffe für Dosis-Wirkungs-Beziehungen - diskutiert am Beispiel gesundheitsgefährdender Stoffe". In: Winter, G. (ed.): *Grenzwerte*, Düsseldorf: Werner, 27-35.

Böhm, M. 1991: "Grenzwerte - von der unzureichenden Umsetzung gesetzlicher Schutzziele". *Öko-Mitteilungen* 2/91, 24-29.

Bollschmiter, K. H. 1990: "Analytische Grundlagen zur Ermittlung von Grenzwerten". *Umweltmagazin*, 6, 7-10.

Bundesimmissionsschutzgesetz 1974: Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnliche Vorgänge. Bonn: Bundesgesetzblatt.

Campbell, J. 1983: "Ambient stressors". *Environment and Behaviour*, 15, 335-380.

Covello, V. T., Winterfeldt, D. v. & Slovic, P. 1986: "Risk communication - A review of the literature". *Risk Abstracts*, 3, 171-181.

Dekoning, H. W. 1987: *Setting environmental standards. Guidelines for decision-making*. Geneva: World Health Organization.

Der Rat von Sachverständigen für Umweltfragen 1987: *Umweltgutachten 1987*. Stuttgart: Kohlhammer.

Deutsches Institut für Normung (DIN) (ed.) 1987. DIN 18005: *Schallschutz im Städtebau. Berechnungs- und Bewertungsgrundlagen* (Teil 1, 5/87). Berlin.

Dienel, P. C. 1978: *Die Planungszelle - eine Alternative zur Establishment-Demokratie*. Opladen: Westdeutscher Verlag.

Dimento, J. F. 1986: "Der Consensus-Workshop: Ein geeignetes Forum für Grenzwertsetzung". In: Winter, G. (ed.): *Grenzwerte*, Düsseldorf: Werner, 103-110.

Dimento, J. S. 1981: "Making useable information on environmental stressors - Opportunities for the research and policy communities". *Journal of Social Issues*, 37, 173-204.

Douglas, M. & Wildavsky, A. 1982: *Risk and culture: An essay on the selection of technical and environmental dangers*. Berkeley: University of California Press.

Edwards, W. & Winterfeldt, D. v. 1987: "Public values in risk debates". *Risk Analysis*, 7, 141-158.

Eimeren, W. v., Faus-Kesseler, T., König, K., Lasser, R., Rediske, G., Scherb, H., Tritschler, J., Weigelt, E. & Welzi, G. 1987: *Statistische und methodische Aspekte von epidemiologischen Studien über die Wirkung von Umweltfaktoren auf die menschliche Gesundheit*. Heidelberg: Springer.

Evans, G. W. (Ed.) 1983: *Environmental stress*. Oxford University Press.

Feldhaus. G. 1979: "Zumutbarkeitsgrenzen als Wege zur Konfliktlösung am Beispiel des Immissionsschutzrechts". *Deutsches Verwaltungsblatt*, 94, 301–306.

Fischhoff, B., Lichtenstein, S., Slovic, P., Derby, S. L. & Keeney, R. L. 1982: *Acceptable risk*. Cambridge University Press.

Fluglärmschutzgesetz (FlSchG) 1971: Gesetz zum Schutz gegen Fluglärm vom 30.3.1971. Bonn: *Bundesgesetzblatt*.

Franck, K. 1984: "Exercising the ghost of physical determinism". *Environment and Behaviour*, 16, 411–436.

Gefahrstoffverordnung (GefStoffVO) vom 26.8.1986. Bonn: *Bundesgesetzblatt*.

Grimme, L. H., Faust, M. & Altenburger, R. 1986: "Die Begründung von Wirkungsschwellen in Pharmakologie und Toxikologie und ihre Bewertung aus biologischer Sicht". In: Winter, G. (ed.): *Grenzwerte*, Düsseldorf: Werner, 35–49.

Gross, R. 1980: "Gesundheit und Krankheit in ihren verschiedenen Aspekten". *Deutsches Ärzteblatt*, 77, 1397–1406.

Gummlich, H. 1989: "Zur Entwicklung der Geräuschbewertung in Wissenschaft und Administration". *Zeitschrift für Lärmbekämpfung*, 36, 105–113.

Held, M. (ed.) 1988: *Chemiepolitik: Gespräch über eine Kontroverse*. Weinheim.

Hoechst AG (ed.) 1989: *Das Risiko und seine Akzeptanz* (Hoechst-Gespräch 1988). Bonn.

Interdisziplinärer Arbeitskreis für Lärmwirkungsfragen 1990: *Gutachterliche Stellungnahmen zu Lärmwirkungsbereichen* (1982–1990). Berlin: Umweltbundesamt.

Irle, M. 1974: "Die Anwendbarkeit der Ergebnisse". In: *DFG-Forschungsbericht: Fluglärmwirkungen – Eine interdisziplinäre Untersuchung über die Auswirkungen des Fluglärms auf den Menschen*, Boppard: Boldt.

Jungermann, H., Kasperson, R. M. & Wiedemann, P. M. (eds.) 1988: *Themes and tasks of risk communication* (Proceedings of an International Workshop at the KFA Jülich). Jülich: KFA-Report.

Jungermann, H., Rohrmann, B. & Wiedemann, P. 1990: *Risiko-Konzepte. Risiko-Konflikte. Risiko-Kommunikation*. Jülich: Programmgruppe Mensch-Umwelt-Technik des Forschungszentrum Jülich.

Jungermann, H. & Slovic, P. 1991: "Die Psychologie der Kognition und Evaluation von Risiko". In: Bechmann, G. (ed.): *Risiko und Gesellschaft*, Opladen: Westdeutscher Verlag.

Kleindorfer, R. P. & Kunreuther, H. C. (eds.) 1987: *Insuring and managing hazardous risks: from Seveso to Bhopal and beyond*. Berlin.

Kortenkamp, A., Grahl, B. & Grimme, L. H. (eds.) 1988: *Die Grenzenlosigkeit der Grenzwerte*. Karlsruhe: C. F. Müller-Verlag.

Krimsky, S. & Plough, A. 1988: *Environmental hazards-Communicating risks as a social process*. Dover: Arborn.

Kutscheidt, E. 1982: "Öffentliches Immissionsschutzrecht". In: Salzwedel, J. (ed.): *Grundzüge des Umweltrechts*, Berlin: E. Schmidt, 237-287.

Kutscheidt, E. 1989: "Rechtsprobleme bei der Bewertung von Geräuschimmissionen". *Neue Zeitschrift für Verwaltungsrecht*, 3, 193-199.

Kutscheidt, E. 1990: "Anforderungen an die Grenzwertdefinition und -ermittlung aus der Sicht der Verwaltungspraxis". In: VDI (ed.): *Technik zum Schutz der Umwelt*, Düsseldorf: VDI-Verlag, 43-57.

Majone, G. 1982: "The uncertain logic of standard setting". *Zeitschrift für Umweltpolitik*, 4, 305-311.

Milles, D. & Müller, R. 1986: "Die relative Schädlichkeit industrieller Produktion. Zur Geschichte des Grenzwertkonzepts in der Gewerbehygiene". In: Winter, G. (ed.): *Grenzwerte*, Düsseldorf: Werner, 227-263.

Nicklisch, F. 1988: "Grenzwerte und technische Regeln aus rechtlicher Sicht". In: Nicklisch, F. (ed.). *Prävention im Umweltrecht*. Heidelberg: C. F. Müller Verlag.

O'Riordan, T. 1988: "The right to know and community dynamics". In: Jungermann, H., Kasperson, R. E. & Wiedemann, P. M. (eds.): *Risk communication*, Juelich: Proceedings of the international workshop on risk communication, 87-105.

Otway, H. & Peltu, M. (eds.) 1985: *Regulating industrial risks-Science, hazards, and public protection*. London: Butterworth.

Patton, M. Q. 1986: *Utilization-focused evaluation*. London: Sage.

Rohrmann, B. 1984: *Psychologische Forschung und umweltpolitische Entscheidungen: Das Beispiel Lärm*. Opladen: Westdeutscher Verlag. (a)

Rohrmann, B. 1984: "Psychologische Kriterien für die 'erhebliche' Belästigung. In: Schick, A. & Walcher, K. P. (eds.): *Beiträge zu einer Bedeutungslehre des Schalls*. Berne: Peter Lang, 139-150. (b)

Rohrmann, B. 1988: "Forschung zu Umweltstressoren als umweltpolitische Entscheidungshilfe". In: Lösel, F. & Skowronek, H. (eds.): *Beiträge der Psychologie zu politischen Planungs- und Entscheidungsprozessen*, Weinheim: Deutscher Studienverlag, 175-181.

Rohrmann, B. (1991): "Entwicklung von Wirkungsmodellen zur Reaktion auf Umweltstressoren". In: Hildebrandt, L., Rudinger, G. & Schmidt, P. (eds.): *Kausalanalyse in der Umweltforschung*, Stuttgart: Fischer.

Rohrmann, B. 1991: *A survey of social-scientific research on risk perception*. Research Center Juelich: Studies on Risk Communication.

Rohrmann, B., Wiedemann, P. & Stegelmann, H. U. (eds.) 1990: *Risk communication - An interdisciplinary bibliography*. Juelich: Research Center, Program Group MUT:

Rossi, P. H. & Freeman, H. E. 1985: *Evaluation: A systematic approach* (3rd. ed.). Beverly Hills: Sage.

Salter, L., Leiss, L. & Levy, E. 1988: *Mandated science: science and scientists in the making of standards.* Dordrecht: Kluwer.
Salzwedel, J. 1987: "Risiko im Umweltrecht – Zuständigkeiten, Verfahren und Maßstäbe der Bewertung". *Neue verwaltungswissenschaftliche Zeitschrift*, 4, 276–279.
Siebert, H. 1987: "Umweltschäden als Problem der Unsicherheitsbewältigung: Prävention und Risikoallokation". In: Bayerische Rückversicherung (ed.): *Gesellschaft und Unsicherheit.* Karlsruhe: VVW.
SRU 1987 – see Der Rat von Sachverständigen für Umweltfragen.
Störfallverordnung (12. BImSchV) vom 19.05.1988. Bonn: *Bundesgesetzblatt.*

TA Lärm: *Allgemeine Verwaltungsvorschrift über genehmigungsbedürftige Anlagen nach § 16 der Gewerbeordnung: Technische Anleitung zum Schutz gegen Lärm 1968.* Bonn: Supplement to Bundesanzeiger No. 132 of 26.7.1968.
TA Luft: *Erste Allgemeine Verwaltungsvorschrift zum Bundesimmissionsschutzgesetz: Technische Anleitung zur Reinhaltung der Luft 1974.* Bonn: Bundesgesetzblatt, 28.8.1974.

Umweltbundesamt (ed.) 1987: *Soziale und psychische Auswirkungen von Umweltbelastungen auf die Bevölkerung.* Berlin: UBA-Texte 15/87.
Umweltbundesamt (UBA) (ed.) 1990: *Daten zur Umwelt.* Berlin: UBA.
Umweltbundesamt (UBA) (ed.) 1989: *Lärmbekämpfung '88.* Berlin: Erich Schmidt.
Uth, H.-J. 1990: *Risiko-Kommunikation in der Chemie.* Forschungszentrum Jülich: Arbeiten zur Risiko-Kommunikation, Vol. 11.

Verein Deutscher Ingenieure (VDI) 1990: *Technik zum Schutz der Umwelt – Grenzwerte und Grenzwertfindung.* Düsseldorf: VDI-Verlag.
Verein Deutscher Ingenieure (VDI) (ed.) September 1985: Richtlinie 2058: *Beurteilung von Arbeitslärm in der Nachbarschaft.* Düsseldorf: VDI-Verlag.
Vlek, C. & Cvetkovich, G. (eds.) 1989: *Social decision methodology for technological projects.* Dordrecht: Kluwer.
Vogel, A. O. 1980: "Die Problematik legislativer Grenzwertentscheidungen – Eine Herausforderung für Politik und Wissenschaft". *Zeitschrift für Lärmbekämpfung*, 27, 198–204.

Wagner, M. 1990: "Definition von Grenz-, Richt- und Anhaltswerten". In: VDI (ed.): *Technik zum Schutz der Umwelt*, Düsseldorf: VDI-Verlag, 11–31.
Werbik, H. & Kaiser, H. J. 1984. "Zum Problem der Anwendung empirischer Forschungsergebnisse": In: Roth, E. (ed.): *Sozialwissenschaftliche Methoden*, Munich: Oldenbourg, 658–674.
Wiedemann, P., Femers, S. & Hennen, L. 1991: *Fallbeispiele für innovative Ansätze der Risiko-Kommunikation im Bereich der Entsorgungswirtschaft.* Jülich: Forschungszentrum Jülich, Arbeiten zur Risiko-Kommunikation, Vol. 18 (a).
Wiedemann, P., Femers, S. & Hennen, L. 1991: *Bürgerbeteiligung bei entsorgungswirtschaftlichen Vorhaben.* Berlin: Erich Schmidt. (b)

Winter, G. 1986: "Einführung". In: Winter, G. (ed.): *Grenzwerte*, Düsseldorf: Werner, 1-27. (a)

Winter, G. (ed.) 1986: *Grenzwerte. Interdisziplinäre Untersuchungen zu einer Rechtsfigur des Umwelt-, Arbeits und Lebensmittelschutzes*. Düsseldorf: Werner. (b)

Wottawa, H. & Thierau, H. 1989: *Lehrbuch Evaluation*. Berne: Huber.