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RISK DECISIONS AND NUCLEAR WASTE

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Abstract:

The risk concept is multidimensional, and much of its contents is lost in the conventional reduction to a unidimensional and quantifiable term. Eight major dimensions of the risk concept are discussed, among them the time factor and the lack-of-knowledge factor. The requirements of a rational discourse are discussed, in general and in relation to risk issues. It is concluded that no single method for the comparison and assessment of risks can be seen as the only rational method. Different methods can all be rational, although based on different values. Risk evaluations cannot be performed as expert assessments, divorced from the political decision process. Instead, risk evaluation must be seen as an essentially political process. Public participation is necessary in democratic decision-making on risks as well as on other issues. Important conclusions can be drawn for the management of nuclear waste, concerning specifications for the technical solution, the need for research on risk concepts, and the decision-making process.

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1. Introduction

Nuclear waste is a technological challenge. But it is also a challenge to the political systems of the nations concerned. The question has often been raised: Are we able to make rational decisions in an issue that is at the same time so technically involved and so laden with conflicting emotions as is this one?

In order to answer this question we need a careful analysis of the two concepts "risk" and "rationality". Sections 2-3 will be devoted to the risk concept and section 4 to rationality. In section 5, conclusions for the nuclear waste issue are drawn from the more general results of the previous sections.

2. The word "risk"

Scientific and technical language needs more precise terms than those of everyday language. In many cases this is achieved by the introduction of new words. In other cases, everyday words have been redefined and given more restricted meanings. Some such scientific redefinitions have been accepted in everyday language. We do not any longer call a whale a fish, and contrary to our ancestors we call the sun but not Venus a star.

There are many words, however, that have one meaning in everyday language and another meaning in scientific language. They may either be everyday words redefined by science or scientific words that have escaped into everyday language where they have been given a less precise meaning. "Intelligence", "energy", "inheritance" and "risk" are among these words.

This double use is of no disadvantage if it is commonly understood that the word has two meanings, none of which should replace the other. Thus no geneticist would criticize a person who said that he had inherited a sum of money, or claim that "inheritance" means only genetic transference. Such linguistic imperialism does, however, exist in some other cases, perhaps most notably with reference to the word "risk".

The technical term "risk" is conventionally defined as something that can be given a numerical value. The procedure is "to multiply the probability of a risk with its severity, to call that the expectation value, and to use this expectation value to compare risks". (Bondi 1985, p.9) Sometimes the expectation value is called "the risk", sometimes it is only taken as the sole measure of the severity of the risk. In both cases, the concept of a risk is reduced to a unidimensional concept, that can be expressed numerically.

This reduction has most notably been referred to in the assessment of risks in energy production. "The worst reactor-meltdown accident normally considered, which causes 50 000 deaths and has a probability of 10^{-8}/reactor-year, contributes only about two percent of the average health effects of reactor accidents." (Cohen 1985, p.1) Efforts are being made to evaluate radioactive waste management in the same fashion. (Cohen 1983)

In its everyday usage preceding modern technical use, the word "risk" has two closely related main senses. In the first place, it can refer to the estimated probability that an undesirable event will occur. (For example when you say: "The risk is no more than one in a thousand.") In the second place, the word can be used in a more general sense to refer to a situation where it is possible but not certain that an undesirable event will occur. When we talk about "a risk" in this second sense, the concept includes both the probability and the character of the undesirable event. (For example when we talk about "weighing the risk of industrial injuries against the risk of plant shutdown".)

In what follows, I will use the word "risk" in the second, more general sense. Instead of "risk" in the technical sense I propose the term "expected damage". Instead of "risk" in what was called above the first everyday sense, I will use the word "probability".

3. Dimensions of risk comparisons

The severity of a risk depends on many factors. The task of professional risk analysis should be to shed light on these different factors, and certainly not to hide them through reduction to a unidimensional concept that ignores most of them.

In this section, some major factors in risk assessment will be considered. Several of them concern what the negative consequences are that one risks: their character (section 3.1), their magnitude (section 3.4), their distribution in the population (section 3.3), when they take place (section 3.5), and whether they are new or old risks (section 3.7). Further, several of the subsections concern the uncertainty whether these negative consequences will take place: lack of knowledge (section 3.6), the distribution of knowledge among the population (section 3.8), the probability of the negative consequences (section 3.4), and the chances that the individual has to avoid them (section 3.2).

These factors are to a large degree over-lapping. Most of them are, even taken alone, too complicated to be represented in a unidimensional fashion.

3.1 The character of the negative consequences

The first of these variables is how different negative consequences are judged. When, for example, the risks of different chemicals are compared, it is necessary to weigh together the probabilities of death, disablement, different diseases and different kinds of environmental impact. These judgements can be made in different ways, and it would be unreasonable to consider one of them to be the only rational way.

Even the loss of lives can be assessed in different ways. Perhaps the most obvious measures are the number of lives lost and the number of person-years lost. According to the former method, "the death of a healthy 5-year old and an invalid 90-year old count exactly the same". (Keeney 1985, p.126) The latter method would count the death of the 5-year old as the loss of seventy person-years, and the death of the 90-year old as the loss of at most five person-years. Arguments can be given against both these measures, but none of them can be rejected as being irrational.

3.2 Control and free choice

The second variable is the weight given to voluntariness or free choice. The degree of free choice can be illustrated by the following sliding scale:

- harmful impurities in a single brand of cigarettes,

- harmful substances in all tobacco smoke,

- air pollution in the working environment,

- air pollution in the air of big cities,

- pollution of all air.

The degree of voluntariness decreases with each step in this scale.

It is not, however, self-evident how voluntariness should be measured. It seems to have two major aspects, those of sacrifice and of control.

In general, a risk is less voluntary than another risk if its avoidance is connected with a greater sacrifice for the risk-bearer. The measurement of sacrifice can, in its turn, be made in different ways. The risk-analyst may appraise sacrifices according to his own valuations or to those of the risk-bearer. (Some risk-analysts would call the former an "objective" and the latter a "subjective" valuation.) If there are risk-bearers with different valuations of the sacrifices, their valuations can be combined in different ways.

For a risk-bearer to have control over his exposure to the risk, it is necessary (but not sufficient) that he is fully informed about the risk. The informed consent of the patient is legally required for risk-taking in medical treatment (Dillon 1981), and the "right to know" of workers is often referred to in occupational health, although in many countries it is not yet legally protected (Murray and Bayer 1984).

Just as with sacrifice, a risk-analyst may either rely on the control that the risk-bearer himself believes that he has, or make an independent evaluation of the degree of control. (Some risk-analysts would call the former the "perceived" and the latter the "actual" control.) This can give rise to great differences in the result of the evaluation. For instance, most drivers seem to overestimate their chance to avoid accidents on the road. Automated highways would probably not be accepted even if they diminished the probability of accidents, since they would at the same time reduce the degree of control. (Bondi 1985, p.8) There is nothing irrational in this reaction, provided that one does, on reflection, value control for its own sake. Non-voluntary risks are usually regarded as being more undesirable than voluntary risks. On the other hand, risks that are highly voluntary, both in terms of sacrifice and of control, are often far from disregarded. Propaganda is made against smoking, and gladiator contests would presumably not be allowed. The reaction of a society (or recommendations of a risk analyst) to highly voluntary risks is closely related to the degree of paternalism that is accepted or recommended. (Möller 1986, pp.99-102)

3.3 Individual and collective risks

The third variable is the priority that is given to individual risks versus collective risks. This can be illustrated most clearly with reference to risks of death. There, the collective risk depends on the expected number of deaths. The individual risk depends on the probability for a single individual to die on account of the risk factor in question.

It is obvious that the individual risk plays a large role in our notion of risk. In practice, most people would accept an industrial process where 50 000 people all have an individual risk to die of 1 in 100 000. However, very few would accept a process where a particular individual was exposed to a 50 percent risk of death. The collective risk is just as great in both these cases, but the individual risk is perceived as unacceptably high in the second case.

But the individual risk is not the only deciding factor. In connection with repairs of nuclear power plants, the individual risk can, as a rule, be kept very small by using a large number of workers, each of whom is exposed to hazardous radiation for only a few minutes. In many cases, this method can take the place of technical means for reducing the individual risk, but it leads to considerably higher collective risks.

Presumably, most people are unwilling to accept an uncontrolled increase of the collective risk in this manner, even if the individual risk is kept within accepted limits.

The height of chimneys provides a similar example. With a low chimney, only small emissions can be made without exceeding individual exposure limits in the vicinity. With a higher chimney, much greater emissions can be made without exceeding individual exposure limits. "If everybody thinks in the same way, a greater number of similar plants will give rise to a global problem, as in the case of sulphur emissions." (Lindell 1980, p.4)

In other words, it is reasonable to attach importance to both the individual risk and the collective risk. They can be weighed together in different ways.

According to the "de minimis" position in risk regulation, there is "a lower bound on acceptable risk levels, no matter what the associated benefits (are)" (Fiksel 1985, p.258). Proponents of this position have favoured a limit on individual risks, such as "a cutoff level of 10^{-6} individual lifetime risk (of death)" (ibid., p.257). The approach has also been called "the probability-threshold position" (Shrader-Frechette 1985). As should be clear from the above, it implies a disregard for the collective risk that is a rather extreme position.

3.4 Large disasters, and probability

The fourth variable is how to judge improbable but large disasters. A widespread conception is that just as serious a view should be taken of a one-in-a-million probability that a million people will die as of a one-in-ten-thousand probability that 10 000 people will die. However, there is no reason why this should be the only rational view. There are other possible ways to view major disasters.

Some authors have claimed that large accidents should be given disproportionately low weight in comparison to smaller accidents. If a catastrophy takes place in a geographically restricted area, in many cases entire families will be extinguished. Therefore, a smaller number of people will lose a member of their families than if the deaths were evenly distributed in a larger population. (Zeckhauser 1975, Möller 1986, p.113)

A more common claim is that very large disasters should be taken extra seriously, even if they are highly improbable. This could be argued for in a perspective of "a hierarchy of values where values higher up in the hierarchy have an absolute priority that cannot be balanced by deliberation on probabilities against values of lower dignity". (Prawitz 1980) The higher values may refer directly to the loss of a high number of lives. They may also refer to the social upheaval and disruption following a disaster, or to the extinction of the human culture or of the human species threatening for example after a war. Risks of this kind have been invoked in the nuclear energy issue by opponents who claim nuclear accidents to be large enough to have a "special dimension" in risk analysis. These claims have been rejected, among others, by Cohen, who maintains that "the question of a serious national moral problem due to an industrial accident is a phony issue. The human race has endured wars that have wiped out large fractions of the population and numerous other unfortunate episodes compared to which any industrial accident ever considered is trivial." (Cohen 1985, p.2)

3.5 The time factor

The assessment of a risk is also affected by when the negative consequences take effect. Many risk decisions have very long time perspectives. This is true, for example, of impact on the climate, damages to the ozone layer, and the extinction of animal and plant species. As a rule, our decisions in environmental matters will affect ecological conditions hundreds of thousands of years from now. Nuclear waste disposal is by no means unique in this respect.

Should we care at all for the distant future and for future generations? Probably, human nature is such that we "cannot be indifferent even to the most remote epoch which may eventually affect our species, so long as this epoch can be expected with certainty". (Kant 1913, p.162) It is less clear, however, how ethical theories can account for this.

A deontological (duty-based) ethical theory may run into difficulties if it only allows for obligations owed to other human beings. "(W)hy should there be obligations to nonexisting persons?" (Green 1981, p.92) A utilitarian theory may be more suited to argue for caring for future generations, since utility as such is not time-bound. "Hereafter as such is to be regarded neither less nor more than Now." (Sidgwick 1890, p.381) In other words, "(i)f the general maxim is that I ought not to act in a way which will do more harm than good, then the question whether the person I am harming or benefiting is yet alive is, on the face of it, morally irrelevant." (Passmore 1981, p.50) However, as will be seen below, the probability-dependence of utility in most utilitarian theories may give rise to counter-intuitive results when they are applied to risks for future generations.

Probably, the best account for obligations to future generations can be given by moral theories that ascribe a primary value to the continuation or development of human civilization. Burke regarded society as "a partnership not only between those who are living, but between those who are living, those who are dead and those who are to be born". (Burke 1899, p.359)

For an individual, postponement of risks is normally an advantage. For instance, it is worse to have a disease that will kill you after 20 years than one that will kill you within a month/ (Möller 1986, p.109) This argument is not, however, valid when the risk-bearers belong to different time periods. Provided that responsibility is taken for future generations, the issue is rather one of justice between generations. (Rawls 1971, §§ 44-51) Then arguments could be given for considering a negative consequence as more or less serious if it is postponed to future generations.

Many discussions of the time factor have involved some form of discounting of future risks. This idea is taken from financial administration. Someone who wants to have $ 100 in the bank in ten years only has to deposit a much smaller amount today. Seen the other way around, the "present value" of $ 100 ten years from now at a discount rate of 6 percent is $ 56.

Hardin (1981), having planted a redwood tree in his backyard, made a calculation of the discount rate necessary to make it a "sound" investment. The seedling cost him $ 1.00, and the mature tree is supposed to have $ 14 000 worth of lumber in it - but two thousand years from now. This investment "would be justified only if the going rate of interest was no more than 0,479 percent per year. So low a rate of interest has never been known. Plainly I was being a rather stupid 'economic man' in planting that tree. <u>But I planted it</u>." (p. 224) In other words: When long time periods are involved, discount rate calculations lose their credibility, even when applied to money.

In a report for the Swedish National Board for Spent Nuclear Fuel, Bengt Hansson (1983, p. 7-10) points out that the analogy with money is not a tenable argument for the discounting of risk. Instead, he mentions three other arguments for regarding an undesirable event as less serious the longer it takes before it occurs.

The first argument is technological progress.

Hopefully, a case of cancer in a hundred years will be less serious than a case of cancer today, since the chances of survival will have increased.

The importance one attaches to this argument is dependent on one's degree of optimism with regard to technological progress. In a trial in England in 1865 concerning pollution of the Thames, the court ruled that it couldn't concern itself with pollution that would only give rise to "damage in 100 years, when chemical methods may have been discovered to prevent the damage" (Douglas and Wildavsky 1982, p. 23).

Bengt Hansson's second argument is the screening off argument. A very small probability that each generation will exterminate humanity (for example via a nuclear war) is enough to make it highly unlikely that mankind will be around in a hundred thousand years. If an undesirable event is put off far into the future, it will then be very improbable that it ever occurs. This argument relies on the common utilitarian standpoint that utility "has a weight according to its degree of probability". (Sprigge 1968, p.263)

This probability effect can be very strong. "Extremely small differences in the assessment of this probability can therefore be completely decisive in determining what attitude should be taken towards the risks associated with the disposal of spent nuclear fuel." (Hansson 1983, p.10) There is reason to underscore the word "can" in the quoted sentence. It is far from self-evident that such factors should be decisive. It can also be argued that our generation has an obligation to live as if we will have human successors in hundreds of thousands and millions of years.

His third argument is perceived risk. A negative event is perceived as being less disconcerting if it will take place far off in the future.

A fourth argument, not mentioned by Bengt Hansson, is the unpredictability of future values. When it comes to future generations, "(w)e cannot presume to know their values or desires, literally do not know what will be "good" for them". (Derr 1981, p.38, cf. Golding 1981) However, this argument cannot be carried very far, since "we do know with a high degree of certainty the basic biological and economic needs of future generations". (Kavka 1981, p.111, cf. Green 1981, pp. 95-96) In most cases, public debate on our responsibilities for future generations is concerned with such basic needs.

Callahan (1981) has compared this responsibility in ignorance of future desires with the responsibility of a parent to a child. The parent does not know exactly what the child needs, but "can only act in terms of what it appears that the child needs, beginning with the minimal requirements of physical survival". (p.84)

In the theoretical literature very little has been said about arguments for regarding an undesirable event as more serious if it occurs far in the future than if it occurs now. Reasons can, however, be given for such a point of view.

One such argument is technological regression. There is a risk that mankind will lose the technical capabilities to solve problems that we are able to solve today. This could be due to loss of knowledge or to depletion of natural resources.

A second argument is political changes. It is, for example, possible that political changes in the future will lead to neglect of a waste repository that requires supervision.

A third argument is changes in values. We generally take a more serious view of health risks nowadays than earlier generations did. If it is judged probable that future generations will have even stricter requirements, this can be advanced as a reason for making stricter requirements e.g. on radiation protection as it affects future generations than on radiation protection as it affects the present generation. (Naturally, the opposite prediction regarding changes in values will lead to the opposite conclusion.)

3.6 Decisions under uncertainty

The sixth variable is how to deal with lack of information. For example, how should one compare the handling of a chemical which, according to epidemiological studies, kills one worker out of a hundred thousand to the handling of a chemical whose possible effects on human health are as yet unknown? There is no clear-cut rational formula for this.

In decision theory, many competing strategies have been developed for decisions under uncertainty. Since many risks are very incompletely known, the choice of such a strategy can highly influence the result of risk assessments.

As was pointed out by Prawitz (1980), it is possible to construct chains of events leading from almost any human activity to a disaster. Not all such theoretical possibilities have to be considered. It is difficult, however, to draw the line. As one example, in the heydays of the polywater hypothesis, Nature printed a warning against producing polywater, since it might "grow at the expense of normal water under any conditions found in the environment", thus replacing all natural water on earth and destroy all life on this planet. (Donahoe 1969). It is by no means self-evident whether, and then on what grounds, this argument should have been disregarded. Similar ideas can be produced for any sufficiently new and untested phenomenon brought into existence by science or technology.

3.7 New and old risks

There is a strong tendency to put higher demands on new risks and on new technology. This has often been seen as an irrational fear of the new. In many cases, however, it is rational enough. Firstly, if new risks are added without the removal of old ones, we have certainly made a loss. Secondly, even if the new risks are replacing old ones, it could be argued that higher demands should be put on protection against the new risks. One reason for this is that lack of knowledge is a more serious drawback when we have no or little practical experience of the risk factor in question. The relevance of this argument depends on how informative the experience is that has been gained from the alternatives that one compares with.

The case of chemical substances serves to illustrate this problem. Systems for the control of new chemical substances are now being introduced in the United States, in the European Community, and elsewhere. Such systems are intended to prevent new chemicals from being brought into use unless their health effects have been investigated and found to be manageable. However, the health effects of most of the chemicals already in use are very incompletely known. Still, their use is continued.

Thus, in practice, for a new chemical the burden of proof is with those who claim it to be safe. For a chemical already in use the burden of proof is with those who claim it to be unsafe. This difference may in part depend on the common assumption that when a chemical substance has been in use for several years, and no serious adverse effects have been detected, we can be fairly certain that there are no such effects. This assumption, however, is an illusion as far as some of the most feared effects are concerned. Cancer and genetic damage have long latency periods, and emerge first after two or more decades of human exposure to the substance.

In the case of chemical substances, practical experience of unproblematic use is informative for the assessment of acute and short-term effects. It is much less informative for the assessment of cancerogenic and genetic effects. Therefore, the lack-of-knowledge argument for the difference in regulatory practices between new and old chemicals is not as strong as might have been believed. There are, however, other arguments for such a difference, such as administrative feasibility.

In the case of power plants, a similar distinction can be made. When comparing the day-to-day emissions of hazardous substances or isotopes from different types of power plants, practical experience from a few years of running the plant is highly informative. On the other hand, when comparing the risks of major accidents, such experience is not very informative - at least not until an accident or two have happened. When opponents of nuclear power have used the lack-of-knowledge argument, they have in general stressed major accidents and not the daily emissions. This seems to be a rational way of judging the decisional consequences of lack of knowledge.

3.8 The availability of knowledge

In the context of nuclear plants, we have often been reminded of another dimension of the lack-of-knowledge factor - namely the question "Whose knowledge?". Some of the knowledge that we have about risks is accessible and intelligable to everyone, but some of it is in its entirety inaccessible to virtually everyone because of its reliance on technical knowledge in several highly specialized fields. Nuclear waste management is an example of a procedure that relies heavily on results from several highly specialized fields of research.

Is it always rational to rely completely on others? Most people would answer no. It may very well be rational to view risks as more serious if the knowledge making them acceptable is directly accessible only to experts than if it is directly accessible to yourself and your peers. This is a factor that has often been insufficiently understood by those who have themselves privileged access to technical and scientific knowledge.

The public often considers reliance on inaccessible technological and scientific knowledge as a factor of uncertainty when judging proposed solutions. Technicians often see this as a matter of how to inform the public. It is, of course, in part. But there is no irrationality in letting it influence the choice of technological methods.

4. Risk decisions in the political process

As is evident from the above rundown of eight factors, very different ways of comparing risks can all be rational. For this reason, it is not reasonable to demand universal endorsement of a single given model for risk comparisons.

It would perhaps be appealing to demand instead that any person who participates in the public discussion on risk evaluation must specify in advance <u>some</u> model for risk evaluations or at least for risk comparisons. However, even this is unreasonable. Decisions concerning risks are so complicated and so intertwined with other judgements in social issues that anyone who bases his evaluations on a particular model must make great simplifications and disregard numerous important but elusive factors.

4.1 Risk decisions as a case of social decision-making

It follows from this that risk evaluations cannot be performed as expert assessments, divorced from the political decision-making process and from social values in general.

Rather, the similarities should be stressed between risk assessments and other issues that the social decision-making process has to handle. Almost all social decisions can be described in terms of avoiding undesirable events. Some of these events can be quantified in a meaningful way, for example health risks and economic risks. Others are virtually impossible to quantify, like risks of cultural impoverishment, social isolation, and increased tensions between social strata.

The various models advocated for risk evaluation involve selecting certain of the more quantifiable factors, for example expected number of deaths and expected economic losses. A comparison is made between the effects of these factors on different alternatives, and the effects are weighed against each other. Some social values necessarily fall outside of such comparisons.

Hence there is a danger for a kind of technocratization, namely that values that cannot be expressed in quantitative terms will be disregarded.

In a different context, namely the much discussed Selfish Voter Paradox, Paul E Meehl (1977, p. 11) has exemplified the poverty of such merely quantitative risk assessments:

> "The empirical probability of an individual voter's behavior determining the outcome of a large scale (e.g., U.S. presidential) election is negligible. Riker and Ordeshook estimate it as one in 100 000 000, and my rough calculations indicate my chances of determining who becomes President are of about the same order of magnitude as my chances of being killed driving to the polls - hardly a profitable venture."

When one chooses a certain model for risk evaluation, one also chooses to disregard all factors that the model fails to take into consideration. Every risk evaluation is based on the decision-maker's general social values. There is no way to depoliticize decisions concerning risks.

4.2 The nature of rationality demands

Nevertheless, there is no reason to abandon the requirement of rationality in discussions concerning risk evaluations. Democratic principles include that anyone who wishes to influence other people's opinions must allow his own arguments to be exposed to criticism and must participate in a public debate that conforms to the rules of a rational discussion. It is therefore reasonable to demand that persons who participate in public debates on risk evaluations - or on any other social issue - do not knowingly advance contradictory claims and that they be willing to alter their own views when these are shown by others to entail contradictions.

Even in the simplest everyday conversation we have some expectations on the intellectual and emotional attitudes of our partners in the conversation. Few of us appreciate conversations with persons who refuse to explain what they mean and who dismiss the arguments of others without providing counter-arguments. In some contexts, among them scientific and scholary discourse and public debates on social issues, misunderstandings can have more serious consequences than in most everyday conversations. In order to be able to communicate adequately in such contexts, we must have stricter demands in these respects on ourselves and on the other participants. We try, in other words, to achieve the ideals of a <u>rational discourse</u>.

A rational discourse does not, as I see it, have any qualities that are absent in everyday conversations. Instead, in pursuing a rational discourse we concentrate on one of the qualities that we aim at in our everyday conversations - namely on <u>communication</u>, on making ourselves as clearly understood as possible. This can in general only be achieved at the expense of other qualities of everyday conversations, such as spontaneity.

The demands on a rational discourse can be summarized as follows:

1. to take the arguments and counterarguments of others seriously, and to accept a tenable argument irrespectively of who proposes it,

2. to present one's arguments so clearly and if necessary in such detail that others can scrutinize them and see how the conclusions are drawn,

3. to use those words that are important for the argument in an as uniform and well-defined way as possible,

4. to adjust one's standpoints when they are shown by others to be contradictory, and

5. as far as possible to found one's judgements in individual cases on more general principles, and to accept the logical consequences of these principles.

A rational discourse demands logical and analytical ability of its participants. But this is not all that is needed. Most of us have witnessed how analytically highly gifted persons have been unable to communicate because of lacking willingness to take part in one another's intellectual endeavours. Rational discourse requires human understanding. Thus rationality depends on emotional as well as on intellectual qualities.

The proposed requirements on a rational discourse are very high demands. In the case of discourse on risks, they are sure to imply that virtually everyone who participates in the public debate on risks should adjust his claims in one or more respects. Thus, my purpose is not to lower the rationality demands, but rather to formulate them in a manner commensurate with the real complexity of risk assessments.

One important consequence of these demands on the discourse on risk evaluations is that spontaneous risk perceptions should not be decisive in the decision-making process. Instead, such risk evaluations should be decisive that arise from these risk perceptions when they are subjected to self-reflection and to the criticism of others.

4.3 Values and facts

A decision concerning risks is based in part on an assessment of the factual consequences of different alternatives and in part on a value-based assessment of these alternatives. It is important to differentiate between these two parts of the decision-making process. Assessing facts is a job for experts, preferably persons with a formal education in the fields involved. The actual decision-making, on the other hand, is not something that can in a democracy be left to experts. It is a matter for the citizens to decide, through the political process, with an equal voice for everyone.

In practice, it is often difficult to distinguish these two parts of the decision process from each other. Values enter into the assessment of facts in different ways. (Hansson 1982, pp. 55-64, Whittemore 1983) What should be done, therefore, is to eliminate values from the factual assessments to as great an extent as possible, and then to clearly indicate the values that could not be excluded and expose them to public view. (This applies not only to values in the ethical sense but also to the many judgements under uncertainty in scientific issues that have to be made.)

The problem of separating facts from values cannot be solved once and for all by any simple organizational or technical means. It is a never-ending struggle that can never be fully won. But the struggle must not be abandoned. To do so would be to surrender the democratic process to the rule of experts.

4.4 Values change

We cannot continuously question all facets of society. At any point in time, only fairly limited aspects of the social order are called into question and regarded as political issues. Viewed in a time perspective of a hundred years or so, public values change greatly and in a way which is generally not possible to foresee. We can therefore expect that future generations in several hundred years will attach great importance to social goals which we have not yet even formulated. Some of the goals towards which we are now working will be seen as outdated and perhaps even primitive.

We make many decisions that we hope and believe will be accepted by future generations. These include, for example, decisions on environmental matters, on land use and on what historical buildings should be preserved. Considering how public values have changed so far through the centuries, there is reason for pessimism about the possibilities to make social decisions to which later generations will not object. This applies not only to decisions which we ourselves consider to be long-range, but also to decisions that we do not believe to have any long-range importance. Presumably, later generations will be critical of actions which we take or fail to take, but whose future importance we do not now realize. Some of the measures we take to build a better future may in retrospect be seen as having had the opposite effect. This has often happened in the past, e.g. when nature has been destroyed or resources depleted. "Much of what has been most devastating has been sincerely done for posterity's sake." (Passmore 1981, p.54)

Nor is there any reason to believe that we will ever achieve a society without unacceptable risks. When we have dealt with those risks that we now consider unacceptable, other risks that we now accept will command our attention. Thus the fighting of risks is a never-ending struggle, where mistakes - as judged by our successors - are virtually unavoidable. This is an insight that might inspire some more humility among those who believe one particular method for risk assessment to be the only rational one.

4.5 Consensus

Democracy requires that the elected officials, who represent the people, pay heed to expressions of opinion and seek solutions that can be accepted by as many as possible. In practice, this is often a balancing act, in issues of risk as well as in all other political issue. On the one side is the danger of populism, i.e. of unprincipled currying of public favour without any basis in political ideas. On the other side is the danger of dogmatism, i.e. of pursuing principles without taking into consideration the wishes of the people one represents. Finding the proper balance between these two extremes is indeed a difficult task for anyone with a political responsibility.

In other words, it is urgent that decision-makers both listen and respond to public opinion. Sometimes such responsiveness to what the people want is considered to be improper tactics and even misguided. However, this criticism is based on a lack of understanding of the workings of democracy and of the responsibility of elected officials.

Compromise and consensus are fundamental values in a democracy, on which the Western parliamentary tradition places a large emphasis. A refusal to compromise would in practice often lead through stalemates to an inability to act.

In the interests of democracy, it is desirable to avoid, wherever possible, narrow majority decisions to accept a risk which a large minority is greatly concerned about. It is also desirable to achieve reconciliation or at least understanding between different views of a particular risk that are prevalent in different segments of the population.

5. Conclusions for the nuclear waste issue

Important conclusions for the management of nuclear waste can be drawn from the above analysis of the risk concept and of the risk decision process. These conclusions concern the specifications for the technical solution (section 5.1), the organization of the decision-making process (section 5.2) and the need for further research on risk concepts and risk perception (section 5.3).

5.1 Specifications for the technical solution

Any method for the disposal of high-level radioactive waste will depend on a complex combination of physical, chemical, geological, hydrological etc. arguments. It is not reasonable to believe that a proof of that kind will be accepted by all experts. Irrespectively of what method one chooses, it will be to some extent controversial in the scientific community.

Since we can never achieve an absolute guarantee against mistakes afflicting future generations, our responsibility towards them has two aspects:

1. To store the nuclear waste in such a way that we have, to the best of our knowledge, solved the problem. Future generations should not, as far as we can now judge, have to do anything in order to protect themselves and their environment from the radioactive waste that we have stored.

2. To store the nuclear waste in such a way that if we have, in spite of all our efforts, made a mistake, future generations should be able to discover this at an early stage and correct the mistake.

These two criteria may be partly contradictory, since criterion (1) may require sealing of the depository in a way that hinders the fulfilment of criterion (2). As yet, however, no study has been made of possible compromises between the two criteria, since technical work in the field has been concentrated on the fulfilment of criteria (1).

This concentration on a final and irreversible solution has its backgrund in the political context of the technical endeavours. The nuclear waste issue has been coupled to the issue of whether or not to use nuclear power. Opponents of nuclear power have an interest to show that the problem is unsolved and perhaps even unsolvable, and proponents have a corresponding interest to show that it is solved or at least solvable. This has lead both groups to concentrate on criterion (1), basically for its implications on the nuclear power issue.

Taking nuclear waste as a problem by itself, however, both criteria have to be taken into account. This will be particulary necessary in the perspective of the need for consensus that was indicated in section 4.5. There are strong reasons to avoid a decision in the nuclear waste issue that a sizable minority sees as an irreversible damage to future generations. Further, there is no chance of finding a storage method that will be universally trusted as a sufficiently safe final solution. The best one can hope for is a method that can be taken by the technological optimists to be a final solution and by the technological pessimists to be a temporary storage, while waiting for an acceptable final solution. To fulfill this criterion as far as possible, the storage method should be not only safe, but safe and reversible.

5.2 <u>The decision-making process</u>

The task of nuclear waste management is not only to find a solution that is acceptable to the experts but to find a solution that is acceptable to the public. Thus, public opinion is not - as some technicians tend to see it - an irrational restriction on the realization of the technical solutions. Instead, the public is the ultimate decision-maker that the technological and scientific experts have to serve.

From what was said in sections 2-4, four demands on an organization for nuclear waste management can be set up.

1. The assessment of waste management methods should not be organized solely as a technological and scientific task for experts. Instead, the assessment should be organized as an integrated part of a political decision process, where technicians and scientists provide the information necessary for the assessment.

2. The public should have access to non-partisan information on the research and development that is being undertaken in order to make possible a safe disposal of nuclear waste.

3. The organizational structure should promote a <u>rational</u> discourse on waste management. In order to do this, the organization should promote independent evaluations and critical assessments of the technical solutions that are developed.

4. The spirit of the research programme and of the decision-making process should be one of compromise-seeking and of striving after consensus.

The Swedish organization for the management of nuclear waste is outlined in the Appendix. I see it as an example of an organizational structure that seems relatively well suited to fulfill these conditions.

The existence of an authority (The National Board for Spent Nuclear Fuel) with evaluative tasks relative to the research programme, separated from the operative organization run by the reactor owners, provides an opportunity for non-partisan information to the public. That board also has the task to promote independent evaluations and critical assessments of the technical solutions that are proposed.

According to the Swedish legislation, comprehensive technical reports on the programme for waste management will be publicly scrutinized every third year. This gives a suitable framework for the public policy discussions necessary in the decision process. It remains, of course, for the organizations in this structure to live up in practice to their difficult tasks. Much depends on the willingness of all parties concerned to understand the nature of the democratic decision procedure and to realize that the earlier criticisms are voiced, the better.

5.3 Research on risk concepts and risk perception

Research on risk concepts and risk perceptions cannot reduce the complexity of the decision-making situation, even though some of its practitioners may sometimes try to give this impression. Nevertheless, such research can make important contributions to the public discussion on how different risks should be assessed. From the rationality requirement follows a need for critical analyses of what decision-makers and opinion-makers say about risks. In this perspective, one purpose of risk research is to indicate the complexity of the decision-making situation, rather than to attempt to find shortcuts to bypass this complexity.

The following six fields of study can all contribute to decision-making on nuclear waste. (The Swedish National Board for Spent Nuclear Fuel has initiated and is in the process of initiating several research projects in all of these fields.)

1. Philosophical studies of the concept of risk, especially as applied to long time periods. As was mentioned above, we need to clarify the meaning of the words we use in order to achieve a rational discourse on risk issues.

2. The historical development of the concept of risk and the perception of risks. It is to be expected that public assessment of risks will change radically even during the first centuries after the disposal of the nuclear waste. These changes are unpredictable, but a slightly better perspective can be gained through studies of historical trends. This is a task for scholars studying the history of ideas and social history. It is of interest to study what risks people have considered to be subject to influence, their acceptance of damage to their health and to the environment, and their view of long-term risks.

3. Psychological studies of how we perceive long time spans and how we judge long-term risks. This is a neglected area where experimental studies are needed.

4. Psychological studies of variables that affect our assessment of the risks of underground waste disposal. It is of interest how a) relatively well-informed specialists and b) the general public perceive such factors as irreversibility, supposedly redundant barriers, whether the waste is radioactive or "only" toxic, etc. It is of interest to know whether expert opinion differs

from public opinion in these questions. Obviously, neither of these opinions is the standard against which the other should be measured. Both are based to a high degree on subjective values, which an attempt should be made to describe.

5. Studies of public opinion. It is of general interest to follow opinion trends in issues related to nuclear waste and its disposal. These issues will remain relevant for a very long time, and it is therefore possible to perform long series of public opinion polls.

6. Review of the nuclear waste debate, in order to analyse the arguments that are used in different phases of the debate.

Research of this type could be given a manipulative purpose: "How can we get people to accept a waste repository?". This could happen if the assumption were that the risk evaluations of experts are correct, whereas those of the concerned public are incorrect. This would particularly be the case if the results of such research were kept secret.

A simple way to avoid the risk of "manipulative research" would be to refrain from conducting research within the sensitive areas mentioned above. However, this is probably an illusory solution. Partisan organizations are sure to perform studies in this field, e.g. public opinion polls, but they are not sure to make them as objective as possible, nor even to publish the results. In order that information of this kind should not be reserved exclusively for the representatives of private interests, it is urgent that the public be given access to the results of research within this field and that this research have a citizen's perspective as its point of departure.

Appendix: Organizing waste management in Sweden

Sweden will cease the production of nuclear power not later than in 2010. The nuclear waste produced till then must be safely handled and disposed. Sweden intends to store its high-level nuclear waste within its own territory. Therefore, research and planning is almost entirely devoted to storage in solid rock.

According to the Swedish legislation, the reactor owners bear the primary responsibility, technically and financially, for the safe disposal of the nuclear waste. Producers of other potentially harmful products, like chemical products, have a similar primary responsibility. Still, the state has the ultimate and long-term responsibility to see to it that the producers fulfill their legal obligations.

1. The major organizations

On the side of the industry, the owners of the four nuclear power plants in Sweden have formed and are the owners of the SKB, the Swedish Nuclear Fuel and Waste Management Co. One of the main objectives of this organization is to fulfill the legal responsibilities of its owners in the field of nuclear waste management. This is confirmed in a consortial agreement between the owners of the SKB. This agreement has been approved by the Swedish Parliament.

The shares of the SKB are held by the four companies roughly in proportion to their total licensed nuclear power generating capacity. (The Swedish State Power Board holds 36%, the Sydkraft AB 12%, the OKG AB 22% and the Forsmark Power Group 30%).

There is one government agency entirely devoted to nuclear waste management, namely the National Board for

Spent Nuclear Fuel. It was set up in 1981 and has tasks in the fields of research and development, financing and information. Its governing body has 11 members that are appointed by the Government. The President of the Board is a former Director General from the Swedish Civil Service. The remaining members of the Board are scientists, specialized in natural sciences and in technology, people with broad banking experience and people with experience from various governmental agencies. Some of the members are proponents of nuclear power, some are opponents and some have no publicly known opinion on the nuclear issue. Some of the members have publicly known political preferences, but none represents a party or any other organization.

The National Board for Spent Nuclear Fuel is a small organization (less than 10 employees). There are two larger authorities, who have regulatory powers and who supervise the safety of nuclear power - and of nuclear waste management - in Sweden. They are the Swedish Nuclear Power Inspectorate (SKI) and the National Institute for Radiation Protection (SSI). These two authorities play an important role in waste management and decommissioning, since they have to study and appraise the nuclear safety and radiation protection of the proposed facilities and processes.

There remains to be mentioned the Consultative Committee for Nuclear Waste Management. The most important task of this committee is to make a yearly report - starting in 1986 - to the Government on the state of knowledge concerning waste management issues. The members are appointed by the Government. Among them are found scientists, an editor of a journal on ethics, and officials responsible for research and development within the three authorities mentioned above.

2. An outline of the workings of the system

The producers of nuclear energy are legally required to perform such comprehensive research and development that is needed in order to ensure the safe handling and final disposal of nuclear waste. This work is in practice carried out by the SKB, the company jointly owned by the reactor owners. Starting in 1986, they have to submit a programme for this work every third year to the National Board for Spent Nuclear Fuel for scrutiny and evaluation. The Board shall report its findings to the Government.

The major method for the government and the National Board to control the research and development work is through comments to the SKB on how their programme should be supplemented or changed. The Board also has its own resources to support research. These resources have been used to strengthen independent competence in relevant fields, to evaluate work done by the SKB, to advance other concepts of waste disposal than the one that is being developed in detail by the nuclear industry, and to support relevant studies in the social and behavioural sciences.

The producers of nuclear energy carry the financial responsibility for all present and future costs for nuclear waste management. Every year they have to submit an estimation of future costs to the National Board. On the basis of these calculations and of its own studies of possible future costs, the Board proposes to the Government a fee to be paid by the reactor owners in proportion to the electric power delivered by their nuclear reactors. The SKB is reimbursed from the National Board for its costs for research and for storage of spent nuclear fuel.

Another task of the National Board is to provide the public with general information on nuclear waste and on the Swedish waste management programme.

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