EUFRAM

Concerted action to develop a European Framework for probabilistic risk assessment of the environmental impacts of pesticides[1]

Work Package 7

Preliminary paper on communicating the results of probabilistic assessments [2]

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1 OBJECTIVES

1. To produce a preliminary paper summarising relevant research on risk communication
2. To identify special challenges associated with communicating probabilistic risk estimates
3. To propose a set of key principals for communicating risk estimates to decision-makers in the EU regulatory context, and to the public
4. The development and testing of appropriate methods for risk communication
5. Development of preliminary guidance on risk communication
6. Testing and refinement of key principals using information from case studies
7. To facilitate coordinated implementation of those research actions by EUFRAM partners and others[4]
8. To collate research results and integrate them into guidance for end-users

Objectives 1-5 are addressed in this paper, which is based on a draft version developed by the WP members together with discussions with other project members at the EUFRAM project meeting on 12-14 May 2003. Objectives 6, 7 and 8 will be pursued throughout the remainder of the project, and especially between May 2003 and June 2004, when the first draft of guidance is due.

2 BACKGROUND

The primary focus of research into risk communication has been directed towards the general public, and not to decision makers and regulators. This is despite the fact that risk analysis is extremely important to regulatory decisions (Bier, 2001). In particular, effective communication about probabilistic risk assessments is a priority (Thompson and Grahame, 1996). This is because the increasing use of probabilistic methods in risk assessment implies that it must also be incorporated into decision-making processes (Apostoklakis, 1990; Thompson, 2002).

Decision-makers are affected by risk perceptions in the same way as are the public, and so knowledge about risk communication applied to the public may also be applied to understanding communication to decision–makers. Decision

[4] EUFRAM does not provide funds for research, although it does provide some funds for "enrichment" of case studies and evaluation of software. Rather the intent is that ongoing activities of partners will be "concerted". This could include forming links between existing activities, adapting those activities if possible to address the needs more closely, and collaborating to initiate new activities.

makers may, on average, have a higher level of education than the general public, but are still influenced by the same factors which influence risk perception in general (Wright, Bolger, and Rowe, 2002). In addition, when the public want information about a risk, they prefer a clear message from technical experts regarding risks and associated uncertainties, including the nature and extent of disagreements between different experts (Denis, 2001). In order to communicate this information to the public, decision-makers must themselves be aware of uncertainties associated with risk assessments, and should therefore have an interest in supporting research to further understand and reduce uncertainties, as well as communicate information about this activity to the public (Krebs, 2001).

Risk assessments are often difficult to understand, laden with assumptions, and controversial. Thus communication about risk assessment to decision-makers and the public is laden with difficulties. As a consequence, public reactions to regulatory activities may be somewhat negative. An example is provided by Jensen and Sandoe (2002), who have observed that the decline in public confidence in food safety continues, despite the creation of new food safety institutions such as the European Food Authority. In part, they argue, this is because communications about food safety issues (including genetic modification) that are based on scientific risk assessments do not reassure the public. These authors argue that

> "risk assessments are determined by the exact choice of putative hazard….to be assessed for possible unwanted consequences, and by the exact demarcation in time and space of the possible consequences to be addressed…… These choices clearly affect the outcome of the risk assessment, but they are not themselves the results of a scientific process".
>
> Jensen and Sandoe, 2002, page 247

Thus arguments embedded in risk communication that risk assessments exist purely in an"objective reality" may be regarded with some cynicism by decision-makers and the public alike.

The need for these choices to be considered explicitly and scientifically is emphasised by some authorities, for example the US EPA (1998), that refers to this part of the process as "problem formulation". The US EPA also stresses that this should involve dialogue between risk assessors (scientists) and risk managers (decision-makers) and other interested parties to ensure that the eventual risk assessment is formulated appropriately. In practice, however, problem formulation is often perfunctory and poorly documented. Furthermore, most regulatory assessments are restricted in scope (e.g. addressing specific hazards and routes of exposure) and simplistic (e.g. focussed on a hypothetical worst case scenario). This may be partly for reasons of efficiency (avoiding a complex assessment where a simple one is sufficient) and partly due to limitations in scientific knowledge (e.g. lack of data to estimate some routes of exposure).

The scope of the current paper is to briefly review research into risk assessment and risk communication, and to identify some key challenges specifically associated with the communication of probabilistic risk assessment and uncertainty to both decision-makers and the public. From this will be developed recommendations regarding best practice in communication of probabilistic risk assessments.

3 RESEARCH ON RISK PERCEPTION AND COMMUNICATION

Research on risk perception and risk communication has been extensively reviewed elsewhere. For the purposes of the current discussion the main outcomes of research in this area will be summarized (for more extensive reviews, see Bier, 2001; Fischhoff, 1995; Schütz, Wiedemann and Gray, 2000; Sjöberg, 2000; Slovic, 2000).

Early research into public risk perceptions focused on the nuclear industry and issues of power plant safety and radioactive waste management. Public negativity and resistance to the nuclear industry in Europe and North America has been well documented, and is paralleled by increased public concern about emerging technologies in general (Bauer 1995). From this early research, public risk perceptions have been shown to be particularly important determinants of public responses to different hazards in various areas. These include, for example, food safety (Fife-Schaw and Rowe, 2000; Verbeke and Viane, 1999; Verbeke, 2001; Frewer and Salter, 2002), the biosciences, (Frewer *et al*, 1997), and possible unintended negative environmental and health impacts of technology (Levidow and Marris 2001). Other areas (for example, health risk from naturally occurring radon, and other natural hazards) have also been considered (see, for example, Sandman *et al*, 1987; Slovic 1987).

People's responses to different risks are *socially constructed.* In other words it is influential psychological factors that are important in influencing people's responses to a particular hazard. These psychological elements are robust and stable across time, although the extent to which people perceive different factors to be associated with different hazards may co-vary with external events (Kasperson *et al*, 1988; Frewer, Miles and Marsh, 2002). In contrast, the technical risk estimates traditionally provided by experts do not influence people's behaviours and responses in the same way as their risk perceptions. For example, a risk that people perceive to be involuntary in terms of their choice over personal exposure is more threatening than one that they choose to take, even if the probability of harm is the same, or possibly even less. For similar reasons, naturally occurring risks are less threatening than hazards which are technological in origin, and people fear potentially catastrophic hazards more than those which affect a similar number of individuals but at different times (see

Katsuya 2001 for examples from the nuclear area; Slovic, 1993 for examples contrasting technological and natural risk).

Other concerns are very specific to particular hazard domains (for example, see Miles and Frewer, 2001). For this reason, public perceptions of risk have often been dismissed on the basis of "irrationality", and have tended to be excluded from policy processes by risk assessors and managers. In other words, the application of arguments associated with rationalist interpretations of scientific evidence has permitted elite groups to dismiss such public reactions as inappropriate and irrelevant. However, it is these public concerns (and of course behaviours which result from risk perceptions) that have direct consequences for human health, food safety and security, economic expansion and international regulation. Public concerns influence consumer behaviour, citizen support of environmental pressure groups, and political preferences of voters during elections. Otway (1987) has observed that effective risk management involves structuring decision-making processes in such a way that they can accommodate broader social concerns and provide institutional forms in which these social concerns can be discussed. In particular, societal priorities for risk mitigation activities may not align with those identified by expert groups. However, dismissing the former as irrelevant may result in public outrage, and increased distrust in the motives of regulators and industry. Awareness and understanding of public concerns is also the basis for the development of an effective risk communication strategy, as these concerns should be explicitly addressed as part of the communication process.

Finally, many potential hazards are associated with benefits both for individuals and society. However, there may be disagreements between different sectors or society as to what constitutes a desirable benefit, and this should also be understood as part of the risk management process (for example, see Frewer, 1999). It is important to be able to assess whether these are important and desirable to the extent that they offset negative risk perceptions associated with a particular hazard (Alkhami and Slovic, 1994; Bauer 1995).

There is also a public perception of cost/benefit balance, which is not necessarily the same as risk/benefit trade-off. For example, when considering the balance of ethical cost / benefit, as in the case of human embryo research, animal research and so forth, the issue to assess is whether the potential benefits of an activity are justified on ethical grounds. Clearly there are benefits associated with the use of pesticides in terms of the efficiency of agricultural systems, and an assessment of both societal and environmental benefits must be made.

4 CHALLENGES ASSOCIATED WITH COMMUNICATING PROBABILISTIC RISK ESTIMATES

One distinction that needs to be made when developing an effective communication framework to communicate uncertainty is the distinction between outcome uncertainty *("what might actually happen and with what probability*") and assessment uncertainty *("to what extent are the results of the analysis likely to change with additional information*") (Brown and Ulvilla, 1987). Brown and Ulvilla note that *outcome uncertainty* is the only communication issue relevant during a *crisis*, where immediate responses are needed. An alternative view is that all uncertainties should be discussed with all key stakeholders as part of the process of crisis management. However, assessment uncertainty is an important factor in deciding *how* to act, i.e. whether to reduce risk (through mitigation action) or reduce uncertainty (through focused research activity). Of course other factors also influence this decision (e.g. the severity and immediacy of the potential risk, the cost and side-effects of mitigation options, and the cost and time required for research). Therefore these other factors would be needed in communicating to decision-makers, even in a crisis, unless it were a crisis of extreme immediacy (for example when there is a timescale of only minutes to hours for responses to be made). Communication about *assessment uncertainty* is more relevant when there is sufficient time and resource available to facilitate the collection of more data. Thus the information requirements of decision-makers are different according to the immediate time pressures and whether the risk is chronic or presented in a crisis context. It is important to communicate information about the differences between assessment uncertainty and outcome uncertainty as both have different implications for decision-makers, and subsequent resource allocation and risk mitigation activity and risk communication. In addition, communicators must distinguish between *risk uncertainties* and *risk variability*. Under conditions of risk variability, the risk varies *across* a population but the distribution is well known. Understanding variability may also have implications for the allocation of resources to risk mitigation activities, and this must be communicated (Morgan and Henrion, 1990). Thompson (2002) notes that because uncertainty differs significantly from variability, there are therefore differences in communication needs between the two cases. Uncertainty arises from lack of perfect knowledge, and may implicate communication about weaknesses in risk characterization models. In contrast the focus of communication about risk variability is that different individuals within a population are certainly going to experience difference levels of risk. Key challenges for communication with decision-makers are summarized in text box 1.

An important aspect of developing effective communication with respect to risk management and risk communication, particularly relevant to environmental aspects of pesticides, is the availability of clearly *described protection goals* (which may differ between different types of ecosystem). For example, in the Netherlands the general public may less concerned by environmental pollution of an agricultural drainage ditch compared to the Waddensea (a large area of water). One of the challenges for environmental risk communication is effective incorporation of protection goals, and discussion of these goals in a spatio-temporal context.

Text box 1. Challenges for communication about probabilistic risk assessments

- Identification of what is useful in communication with decision-makers?
- How to communicate probabilities, and to distinguish those that relate to frequencies and those that relate to uncertainty?" *Lack of consensus amongst scientists about this distinction and the terminology makes it doubly hard to communicate them to decision-makers and the public.*
- How to effectively communicate assessments between *assessment uncertainty and outcome uncertainty*?
- How to effectively communicate differences which distinguish between *uncertainty* and *variability*?
- How to communicate differences between *uncertainty about the effectiveness of a risk reduction measure*, and *uncertainty about the magnitude of the risk* that it is designed to address?
- What *format* is optimal in communication[1]?
- How to communicate risk estimates that involve multiple dimensions, (e.g. severity of the impact and its frequency in space and time = 3 dimensions)?
- How will the public react to these *differences? How can this information be obtained and communicated to decision-makers? E.g. graphical versus numerical versus textual approaches*
- How might wider social values be integrated into these communication processes?

([1] Thompson and Bloom, 2000)

5 KEY PRINCIPLES FOR COMMUNICATING RISK ESTIMATES TO DECISION-MAKERS IN THE EU REGULATORY CONTEXT

The American Industrial Health Council has provided a report summarizing what decision-makers ask for in terms of risk information (text box 2). This is, of course, relevant to the development of an effective framework for the communication of probabilistic risk assessments.

When assessing risks it may be useful to present different decision options and their possible (environmental) consequences, so that decision makers have options to choose the most effective response. This approach might also be a transparent way to communicate decisions to other stakeholders, assuming there is explicit differentiation between probability and variability.

Text box 2 - What do decision-makers ask for in terms of risk information?

- The presentation of the risk assessment must be comprehensible and understandable
- The applicability of the assessment for public policy decision-making should be clearly stated
- The presentation must be credible and fully defensible
- The risk assessment report should contain a clear and relatively brief summary that includes balanced treatment of all relevant contentious issues
- The basis for the choice of critical assumptions should be described along with discussion and resolution of science issues as far as possible
- Conclusions should be drawn so as to be relevant to the specific risk management policy framework

American Industrial Health Council, 1989, (reported in Bier, 2001)

Reliability of information is likely to be a key issue to decision-makers and to the public, and thus it is necessary to communicate the extent to which a particular assessment is reliable or not. In particular, it is important to communicate information about the *sources of uncertainty* as well as the *magnitude of uncertainty* associated with a particular hazard (National Research Council, 1994). It is also useful to provide information to decision makers regarding the most likely public responses to the various decision options under consideration. Decision -makers will also need information about emerging hazards, which may also be associated with high levels of uncertainty, and the probable public response to these hazards. For this reason, it is important to understand how citizens and consumers are likely to react to *future and emerging potential hazards* as well as those *already effective*. This indicates that there is a need for close co-operation between the natural and social sciences in terms of integrated research activities. In some cases this may require specific research focusing on future and current activities. Decision – makers must also take *public responses to risk uncertainty* into consideration, and this is therefore considered in a following section. Communication with the public should be a dialogue between risk experts (for example risk assessors and risk managers) and the public. Similarly communication between risk decision-makers and risk assessors should also be *interactive*, in order that what and how risks are assessed aligns with the information needs of both risk managers (Bier, 2001) and the public more generally.

6 KEY PRINCIPLES FOR COMMUNICATING RISK ESTIMATES TO THE PUBLIC

There is at the present time increasing societal and political pressure directed towards increased transparency in risk management practices. For this reason, the uncertainties associated with technical risk assessments, upon which risk management decisions are founded, will increasingly be subject to public scrutiny (Frewer *et al*, 2002). For example, an extremely important outcome of the UK BSE enquiry was the recommendation that governments should focus "on the need to be open about uncertainty and to make the level of uncertainty clear when communicating with the public" (H.M. Government, 2000).

Decision-making associated with probabilistic risk estimates is apparently not easy for the general public. For example, there is some evidence that individuals appear to have difficulties in interpreting low probabilities when making decisions (Kunreuther, Novesnky and Kahneman, 2001). Indeed, it seems that few people tend to seek out *probabilistic information* under conditions of uncertainty (Huber, Wider and Huber, 1997). People's risk perceptions are influenced by judgmental biases such as *the availability heuristic*. People estimate the likelihood of an event occurring in relation to the ease with which they can recall past instances of the event. The easier it is to recall a past event, the greater the probability of the event occurring in the future. Other heuristics include *representativeness* (the likelihood of an event is estimated according to the similarity to the class of events of which it is seen as an instance) and *anchoring and adjustment* (in a first step, judgements are anchored on an initial value which is then adjusted according to the present circumstances). While heuristic judgements tend to be quite robust in everyday circumstances, they may lead to systematic biases in people's understanding of probabilistic information (Kahneman, Slovic and Tversky, 1982).

In the past, it has been assumed by experts that the public are unable to conceptualise the scientific uncertainties associated with technical risk estimates, and, moreover, that providing lay people with this information will have very negative effects on public risk perceptions and related attitudes (Wynne, 1992). Johnson and Slovic (1995, 1998) report a series of studies that tested the effects of various uncertainty conditions, reasons for uncertainty, and risk magnitudes, on laypeople's understanding of technical risk estimates. Only 20 per cent of their respondents had difficulties with uncertainty *per se*, unable to distinguish indicate if a reported risk figure was a point estimate or an interval estimate. Among those respondents who understood the concept, reporting of uncertainty had mixed effects. On the one hand, discussion of uncertainty appeared to signal *more honesty*. On the other hand, discussion of uncertainty led *to lower competence ratings of the institutions responsible for risk assessment*. Graphical presentation of uncertainty produced higher comprehensibility ratings, but lower trustworthiness ratings. Conflicting evidence was attributed to the self-interest and incompetence of scientists, and resulted in a higher willingness to accept a worst-case scenario. Moreover, the absolute magnitude of a risk estimate had systematic effects on respondents' confidence in its accuracy: low estimates were deemed more "preliminary", whether uncertainty was mentioned or not.

In line with the experimental evidence reviewed above, some authors have argued that acknowledgement of uncertainty will increase public confidence in regulatory processes (Frewer, 1999). This may be dependent on attitudes and beliefs held by individual members of the public, and the level of trust these individuals have in regulatory bodies that have the remit of consumer and environmental protection at their core. For example, Kuhn (2000) has investigated the effects of communicating environmental risk uncertainty with respondents with both high and low levels of concern about the environment. Kuhn reports that environmental attitudes are a very accurate predictor of environmental risk perceptions if uncertainties associated with assessment are not mentioned. Communicating uncertainty information increased the environmental risk perceptions for people who were initially unconcerned about environmental risk, but decreased risk perceptions for those expressing high initial levels of environmental concern. These results were interpreted as indicating that communication about uncertainty increased the credibility of the communicator, which in turn reduced perceive risk, for those individuals initially cynical about the motives of the communicator.

The results of empirical investigation are somewhat equivocal in terms of empirical findings regarding the communication of uncertainty. For example, it is reported that North American citizens expressed a greater preference for risk reduction under conditions of uncertainty under conditions where the risks were also considered to be catastrophic (Slovic, Fischhoff, and Lichtenstein, 1980), or having negative health impacts (Fessenden-Radon *et al*, 1987). Against this, information about uncertainty has not been found to influence peoples' concerns about the location of other potentially catastrophic hazards such as waste depositories (Bord and O'Connor, 1992). In particular, people need context to draw on their own experiences if they are to be able to evaluate an unfamiliar risk with a low probability (Kunreuther, Novemsky and Kahneman, 2001).

There is also evidence that the public tend to accept emerging technologies if there is admission about uncertainties associated with human health or environmental impact, perhaps because discussion of uncertainty signals honesty (Johnson and Slovic, 1998). Differences between perceptions of uncertainty associated with different risks may also be dependent on other characteristics associated with a specific hazard. For example, Miles and Frewer (2002) report that for some hazards (for example, gene technology) people perceive they have little personal control over exposure. Instead, the exposure of individual citizens to risk is perceived to be under the control of societal institutions, to which accrues responsibility for public protection. Under these circumstances information about uncertainty has a greater impact on public risk perceptions (see also Frewer *et al,* 2002).

A key element in the discussion about the communication of uncertainty may relate to the possibility that the public may interpret scientific uncertainty in different ways. Different types of uncertainty were found to be important to the general public in focus group research reported in Frewer *et al* (2003). These related to *lack of knowledge*, (for example, lack of scientific information regarding a specific risk, or conflicting scientific information or opinion), uncertainty about the *potential impact or extent* of a particular hazard, and the perceived need for *further research to be conducted in order to reduce the uncertainty*. A further issue related to perceptions that regulatory institutions were *withholding uncertainty information from the public*. The acceptability of different types of uncertainty was assessed using survey methodologies sampling beliefs of representative British populations. A key result indicated that the public was more accepting of uncertainty resulting from inadequacies in scientific process per se compared to uncertainty associated with the failure of institutions to reduce scientific uncertainty through conducting appropriate empirical investigation.

Thompson (2002) has concluded that risk communicators (whether to the general public or decision-makers) must distinguish between variability and uncertainty in the risks that they use for risk comparisons, and that there is a need to develop and test strategies for communicating risk uncertainty using both qualitative and quantitative approaches.

7 EXPERIENCE FROM CASE STUDIES

Example 1: blue tits in orchards (Hart, 2002. Hart, in press).

In this example the assessment endpoint was % mortality in local populations of blue tits in the vicinity of orchards sprayed with chlorpyrifos, a pesticide. Two main forms of output were used: a 2D graph showing the probability of differing levels of mortality, and tables showing estimated probabilities of exceeding particular levels of mortality (e.g. 5%, 10% etc).

The Environmental Panel's reactions included the following:

- Potential difficulty using a novel endpoint such as % mortality for decision-making, given the focus of current practice on the TER (toxicity-exposure ratio).
- Expressed concern that the relative complexity of the underlying calculations would increase the risk of error, and make it difficult for regulatory authorities and committees to detect errors or, even, deliberate misuse of probabilistic methods.
- Concern was expressed that, in replacing established precautionary assumptions with empirical data, the probabilistic assessment might have been made unconservative and actually under-estimate risk – again, because of the complexity of the approach they felt unable to judge this.

- The panels were uncertain how to judge the acceptability of any given level of % mortality, given the lack of any established criterion for this.
- The panel felt that probabilistic approaches would be data-hungry and thus resource intensive (even though the example began with a typical basic data set).
- The panel asked for further work to provide a more direct comparison of probabilistic and deterministic approaches: this was understood to refer primarily to the choice of endpoint (TER) and the type and quantity of input data used.

The communication requirements of the panel therefore related to understanding the potential impact of the application of probabilistic assessment, and how these different from deterministic approaches, and understanding the potential for increased error associated with increased calculational errors.

Example 2: Geese and cereals (Hart, 2001, 2002)

This case study was based on an example of a deterministic higher-tier risk assessment taken from the EU Guidance Document on Risk Assessment for Birds and Mammals (EU, 2002, Appendix *). The probabilistic assessment used precisely the same scenario and data as the deterministic one, and was presented in the same format. The assessment endpoint was the TER (toxicity-exposure ratio). The output was presented in tabular form, but showed specified percentiles from a distribution of TERs instead of a deterministic TER for a specific "worst case" scenario. It was demonstrated that the "worst case" TER corresponded to a particular point on the distribution from the probabilistic assessment. In the final Table, the TER percentiles were accompanied by confidence limits showing the effect of uncertainty in selected inputs.

This example seemed to reassure the Environmental Panel about some of the concerns expressed over the previous example, in particular the use of the TER endpoint, and the feasibility of applying probabilistic methods to existing regulatory models and data sets. They concluded that PRA had potential for providing valuable additional information (about variability and uncertainty) during the first tier risk assessment, and that the use of such models would raise a number of useful questions about assumptions that are implicit in current assessments. The Panel suggested that both toxicity and exposure should be treated probabilistically (for simplicity, toxicity had been treated deterministically). The Panel questioned the real meaning of the statement "the TER will fall below 10 on 11% of fields", and how this relates to the real environmental impact. This is somewhat ironic, since their difficulty probably concerned the meaning of the TER – which is the basis of the current deterministic approach - rather than the percentage of fields or the confidence limits. The Panel concluded that further work would be needed to implement probabilistic approaches in a manner suitable for regulatory use.

These examples suggest that communication of probabilistic assessments will be much easier if they use the same assessment endpoint, scenario and model structure as current deterministic assessments. This is not surprising, because it minimises conceptual change and makes the outputs compatible with existing regulatory procedures. It seemed that when these conditions were met, there was less concern about complexity of the underlying calculations, even though this was similar in the two examples. This suggests that probabilistic assessments will be more easily accepted if they use existing endpoints, scenarios and models.

On the other hand, applying probabilistic methods to current assessment endpoints will not make those endpoints more ecologically meaningful. This is not a limitation of probabilistic methods but of the existing endpoints. To address this will require new assessment endpoints (e.g. % mortality), which in turn imply changes in model structure.

The desire for familiar endpoints clearly conflicts with the desire for more meaningful ones. The solution may be to carry out probabilistic assessments for both conventional and new endpoints and present them side by side, at least until the new endpoints become established (which might eventually require changes in legislation). This dual approach would need to be accompanied by skilful presentation and communication of results, by authoritative peer review of the underlying methodology, and, if possible, by validation studies.

8 CONCLUSIONS FOR COMMUNICATION AND CASE STUDIES

These experiences suggest that difficulties communicating probabilistic assessments to date may derive more from changes in the structure and endpoint of the assessment model than the fact that the model is treated probabilistically. Someone who is familiar with TERs is likely to be more receptive to confidence limits on their TER than to a totally new endpoint. The implication is that we need to give as much consideration to the context for communication and what we communicate, as to how we communicate it.

9 IDENTIFICATION OF EMERGING RESEARCH ISSUES

At present, it is not understood how the general public and decision makers percieve the severity of the consequences in terms of the personal consequences for themselves, as well as the relative severity and ecological consequences of impacts on humans relative to vertebrates, invertebrates and plants. The question arises as to whether this is important when considering risk management options.

A second factor, which may be important when considering agricultural pesticides is that of, perceived controllability of possible effects, and the effectiveness of mitigation measures. Public acceptability of risk may be contingent on this factor, particularly if there are differences in opinion between the public, key stakeholders and decision-makers.

Another potential research objective may link to whether the outcome of probabilistic risk assessment can be easily linked to concepts of acceptability of risk and spatio-temporal differences in protection goals (e.g. the precautionary principle, pollution prevention principle, ecological threshold principle, recovery principle, functional redundancy principle). This may be particularly useful for communication directed towards decision-makers.

One of the key issues for the application of probabilistic methods is that they may reveal much more uncertainty than has hitherto been acknowledged. Practical objections, that such assessments are not useful for decision-making, are dealt with in my input to work packages 3, 4 and 5. From a technical point of view, communicating high uncertainty is no harder than communicating low uncertainty. However, communicating previously undeclared uncertainty is likely to create some additional communication problems: (1) it is likely to raise questions about the credibility, honesty and competence of scientists from both decision-makers and public (why didn't you tell us this before?), It will create problems for decision-makers who will have to explain to the public how they will make future decisions in the face of such uncertainty. Overcoming these challenges will require a firm commitment to a more open and participatory style of risk assessment and management, good communication and listening skills on all sides, and lots of time. Development of confidence in the new approaches would probably be facilitated by case studies using well-known examples, and by experimental validation studies where possible.

10 ACTIONS FOR NEXT PHASE OF EUFRAM

EUFRAM

The project meeting on 12-14 May 2003 agreed on the following activities to explore and evaluate the issues and options discussed in this paper.

Action	Who[5]	When
1. To gather further examples from case studies to illustrate communication issues report after second case study meeting	WU	30/3/04
2. Collaborate with the case studies (in WP8 and also outside EUFRAM) to test proof of principals regarding uncertainty analysis with end-user groups	WU	30/3/04
3. Test proof of principals regarding guidelines with endusers	WU	30/0/04

[5] EUFRAM partner acronyms. Wu = Wageningen University.

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ANNEX 1

A quote about what decision-makers want: "Assessors are charged with (1) generating a credible, objective, realistic, and scientifically balanced analysis; (2) presenting information on hazard, dose-response, exposure and risk; and (3) explaining confidence in each assessment by clearly delineating strengths, uncertainties and assumptions, along with the impacts of these factors (e.g., confidence limits, use of conservative/non-conservative assumptions) on the overall assessment. They do not make decisions on the acceptability of any risk level for protecting public health or selecting procedures for reducing risks."[6]
Another one, for ecological risks:

Questions for Risk Managers to ask Risk Assessors regarding risk assessment results (US EPA, 1998);

1. What effects might occur?
2. How adverse are the effects?
3. How likely is it that the effects occur?
4. When and where do the effects occur?
5. How confident are you in the conclusions of the risk assessment?
6. What are the critical data gaps, and will information be available in the near future to fill these gaps?
7. Are more ecological risk assessment iterations required?
8. How could monitoring help evaluate the results of the risk management decision?

Another one, specific to environmental risks of pesticides:
Questions frequently posed by Risk Managers in the US EPA Office of Pesticide Programs (ECOFRAM 1999).

1. What are the effects of concern?
2. Why are they of concern?
3. What is the magnitude and probability of these effects?
4. Will there be population(s) impacts?
5. Will the population(s) recover?
6. Are the effects seen across different species?
7. Will the effects influence the density and diversity of the species?
8. How confident are we in our estimate of the effects?
9. What models did we use? Have they been validated?
10. Are the models widely accepted and scientifically sound?
11. How predictive and confident are we in using the models?
12. Have you completed a comparative analysis of the potential environmental effects with similar compounds and/or alternatives?

[6] GUIDANCE FOR RISK CHARACTERIZATION,U.S. Environmental Protection Agency Science Policy Council, February, 1995.

13. Is there any monitoring data? How have you factored the monitoring data into your assessment?
14. If there are unresolved scientific issues, can data be developed/studies conducted to answer these questions?
15. How long will it take to conduct the studies and how much will they cost?
16. Have other agencies and/or countries assessed the environmental risks?
17. How do our assessments compare with those of other agencies and/or countries?
18. For each question already mentioned are there any mitigation measures (i.e. buffer zones, filter strips, use reduction, etc.) that will eliminate or reduce the calculated risk?
19. Can we measure/monitor to determine if our mitigation measures are working?
20. In summary, help me put this pesticide and its potential environmental risk in perspective.

ANNEX 2

KEY PRINCIPLES of Communication (following discussion at the Wageningen meeting, may 2003)

- Formulate the assessment problem and define the required output at the outset, in close consultation with the decision-maker
- Present probabilistic assessments for conventional and novel endpoints side by side
- Improve communication of the concepts of risk, uncertainty and variability
- This implies seeking a greater scientific consensus (at least within the pesticide field) on the concepts and terminology of uncertainty and variability, and their roles in risk assessment, and communicate these things clearly to decision-makers and the public in each assessment.
- Avoid creating new terms, or new meanings for words that have a well established popular meaning. Avoid or qualify words that have multiple or ambiguous meanings, including “risk” and “probability”
- Use multiple methods of presentation. Always present results both in tabular (numeric) form and in text (narrative) form, and make sure they are consistent with each other. Accompany this with graphical output unless this is found to be positively unhelpful. Experiment with the details of each form of presentation to find the most effective approaches.
- Make use of confidence limits to communicate uncertainty
- Probabilistic output tends to be dominated by complex graphics. Many scientists find it difficult to understand or explain cumulative distribution graphs, whereas most scientists are very comfortable with the concept of confidence limits on numeric estimates. I suspect that the latter will be more easily understood also by decision-makers and the public.

- Establish standard formats for presentation of routine assessments
- Find the optimal format for standard assessments and adopt it as a standard. Use non-standard formats only in special cases where it provides a clear advantage.
- Be as objective as possible about uncertainty
- Don’t conceal or downplay uncertainty, nor exaggerate it. It is dishonest and will undermine scientific credibility in the long term.
- Separate the estimation of risk from the evaluation of its acceptability