Ecological Risk Assessment for Terrestrial Ecosystems in Australia: A summary of recommendations from the Workshop held in April 2004 in Adelaide Australia

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CMIS REPORT 05/03

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March 2005

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Anthropogenic activities invariability lead to the release of hazardous contaminants in the environment and as a result we have a legacy of land and water contamination due to chemicals around the globe. Governments and their agencies are increasingly being expected to intervene to ensure adequate protection of ecosystem and human health from potential exposure to the pollutant chemicals at contaminated sites. Risk assessment is an attractive tool for better measuring and understanding the nature and extent of the risk posed by the contaminants and for informed decision-making about potential mitigation strategies. Human health risk assessment has been the primary focus of early applications of risk assessment approaches (Rechard 1999). Ecological risk assessment has been developed independently and the two are practised separately (Suter 2005). Now, after some two decades of development, Ecological Risk Assessment (ERA) is increasingly useful as a decision making tool – in regulatory, policy, risk management and risk communication arena (Suter 2005, this volume). In Europe, a risk based framework is being promoted in policy, research and land management (CLARINET 2002; Faber 2005 this volume). In some countries e.g. UK, recent environmental legislation has brought ERA in to greater prominence (Pollard *et al*. 2002).

There are several challenges associated with the risk-based approach of land management and decision-making using ERA. Ecological processes are inherently complex, involving a range of environmental compartment (soil, water, air) target receptor (from microbes to mammals) and exposure pathways. At a minimum it requires a multidisciplinary approach to address the complexities. Currently there is a poor understanding of processes governing ecological risks and especially a paucity of ecological relevant input data that is needed and one needs to work in data deficient environment. Furthermore, there is considerable uncertainty associated with the limited data available and this highlights the need for explicit treatment of the uncertainty in ERA.

As Suter (2005, this volume) argues, there is strong demand for simplicity in ERA without sacrificing its robustness. This is associated with increasing expectations of enhanced stakeholder involvement and degree of transparency in ERA and decision making based on ERA.

Current state of ERA use in terrestrial ecosystems in Australia

The risk based approach is increasing being used in Australia (see for example (Muschall and Warne 2003). As in many other countries, Australia has a large number of contaminated sites, some of which have the potential to have off-site impact on the environment (Barzi *et al*. 1996).

Risk assessment is used by various environmental agencies in Australia (Beer and Ziolkowski 1995), such as Department of Environment and Heritage (www.deh.gov.au), as a decision making tool for a range of activities, registration and review of agricultural and industrial chemicals as well as to assess the potential exposure to environmental contaminants (e.g. dioxins, Gatehouse 2004).

The role of ERA in the assessment of site contamination is recognized (e.g. in the National Environmental Protection Measure for the Assessment of Site Contamination – "NEPM") but there is a lack of local data and much further work is needed. The NEPM includes guidelines which describe a clear framework for ecological risk assessment for chemically contaminated soils that can be readily used by state environmental protection agencies and risk assessors, for the protection of terrestrial biota from the adverse effects of chemical contaminants in soil. These guidelines were derived by incorporating various aspects of the Canadian, American and Dutch systems for ecological risk assessment. These guidelines include a three-level approach starting from Level 1 assessment using generic Environmental Investigation Levels (EILs) to Levels 2 and 3 assessment involving site-specific assessments (NEPM 1999).

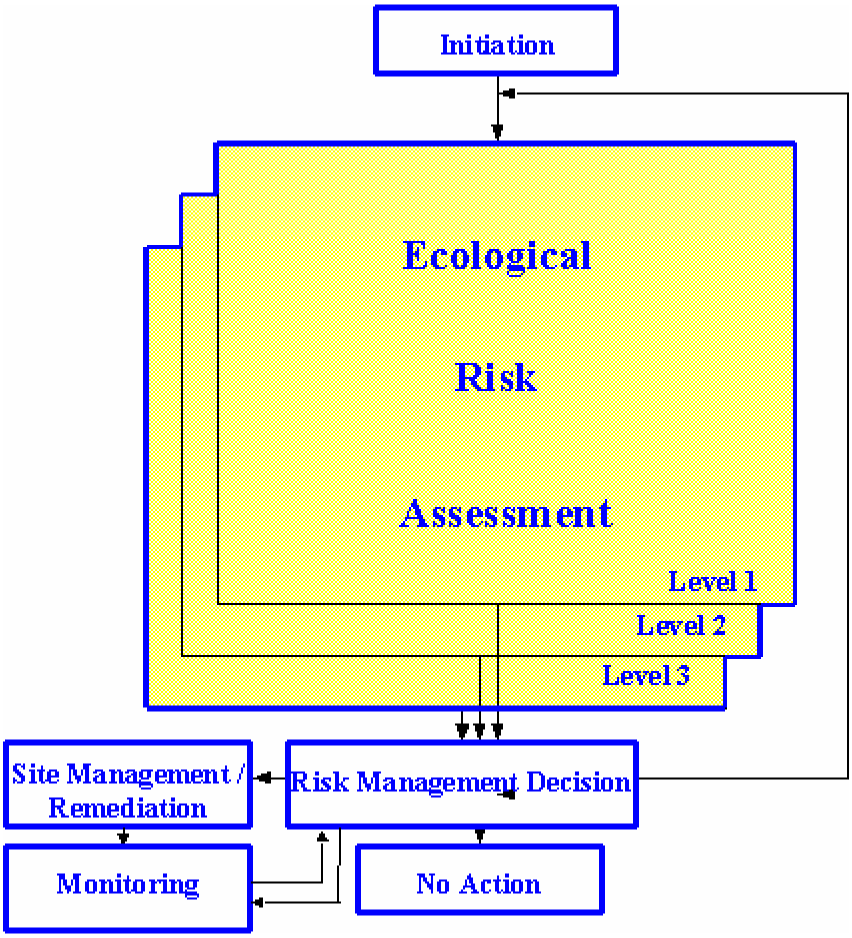

Figure 1: Australian Framework for Ecological Risk Assessment (NEPM 1999)

The primary driver for risk assessments in Australia, and indeed in many countries, is human health while ecological health is less adequately dealt with due to the paucity of data, and so ERA is less developed than human health risk assessment.

This workshop was organised to reduce the gap between the state of human health risk assessment and ERA. The workshop was organised to bring together the existing knowledge in the area of quantitative ecological risk assessment for environmental contaminants, in order to provide a basis for developing a better risk assessment framework for the terrestrial environment. The workshop focused on the contaminants in the environment originating from anthropogenic activities and addressed the components of ERA related to sources, exposure pathways and toxicity to receptor organisms.

Summary of outcomes from the workshop

Wide-ranging discussions were held on a number of topics during the workshop, following the lead papers that were presented and are included in this volume. A précis of discussions and recommendations arising out of these are listed below. The recommendations also take into account the current state of knowledge, the philosophy of a step-by-step progress and practicability.

ERA as a decision-making and/or management tool

ERA provides an objective approach to determine whether there is likelihood of an adverse effect. When done properly, ERA is an excellent communication and management tool. However, there is need for consistency in approach for risk assessment among specialists and appropriate guidance and standardisation are needed, which is expected to help provide uniformity and better prepare the practitioners of ERA. The NEPM (1999) includes a guideline for ERA with a view to promote a consistent approach for chemically contaminated sites in Australia. The workshop advocated the more general application of ERA. As a means of promoting ERA the following recommendation is made.

1. *A nationally consistent approach to ERA, backed up by appropriate training opportunities for both environmental practitioners and environmental*

managers is needed for its further uptake as a decision making and management tool.

Choosing appropriate target receptors in ERA

In choosing target receptors for inclusion in risk assessment, consideration should be given to the ecological relevance of species chosen i.e. how well these represent the functions and structure of the ecosystem/s being assessed, coverage of different trophic levels, species diversity and sensitivity and the level of protection required for the long term time frame but keeping in view its practicability and feasibility.

2. *The receptors should be ecologically relevant. To the extent that is practical, the receptors should be chosen to represent different trophic levels in the ecosystem to be protected.*

Sampling strategy customisation for hazard assessment

There are at least four components of the sampling strategy – design, sample collection and their analyses (e.g. chemical), statistical analysis of the data and communication of results. The number of samples and nature of collection (e. g. composite samples) is often dictated by the costs of fieldwork and laboratory analyses. The sampling strategy needs to be driven by the objective of the assessment. There is no single approach that is appropriate for all cases. For example, composite sampling is not adequate for delineating hot spots, but it may be useful in establishing their existence.

2. *The sampling strategy should be consistent with the objectives of ERA.* ***Spatial and temporal variability and uncertainty need to be adequately accounted for.***

Relevance/limitations of existing ecotoxicological databases

Several relevant and useful ecotoxicological databases are available in Australia and overseas (e.g. the Australian Ecotox data base (Warne and Westbury 1999; Warne *et al.* 1998) and the USEPA Ecotoxicological data base- http://www.epa.gov/ecotox/) , however, there are limitations associated with these, including transcriptional and numerical errors, quoting a wrong unit of measurement and often not providing an adequate reference of the source of information. Furthermore, users need to be aware of the limitations of the data as they relate to single chemicals for single organisms only. There is an ongoing need to update and enhance the quality of databases. Ecotoxicological data based on field exposure are desirable as they can draw together toxicity and bioavailability information.

Both the Australian and the USEP ecotox data bases include some toxicity data based on field exposure and both have some measure of the quality of the data.

3. *It is recommended that the user be careful about source/quality of information in the ecotoxicological database, currency of the data and any transcriptional, numerical and units errors in the data.*

Relevance of aquatic ecotoxicological data to terrestrial ecosystems and of the laboratory data to field

Aquatic ecotoxicological data have limited relevance to terrestrial ecosystems, as the organisms in terrestrial environments are not well represented by the aquatic environment. For example there are very few angiosperms in aquatic environments but they are highly represented on land and there is a lack of ecotoxicological data for angiosperms. Furthermore, the terrestrial ecosystems are less mixed, inherently more variable and relatively more complex that aquatic ecosystems. Nevertheless, some approaches and experience from aquatic ecotoxicology (e.g. sediments) can serve as a useful guide to terrestrial ecotoxicology.

Both laboratory and field experiments have some limitations, but both have their uses. Laboratory toxicological assessments can at least under some conditions predict what is happening in the field and are often needed to obtain causative information. The laboratory results can also serve as a useful guide to field investigation and help interpretation of field data.

4. *Approaches and experience from aquatic ecotoxicology (e.g. sediments) can be and should be utilised for terrestrial ecosystems, however, the very different nature of two types of ecosystems need to be kept in mind. The field and laboratory observations often compliment one another and one is not preferable to another per se. Field observations often need to be underpinned by laboratory experiments that provide causative information.*

Essential Ingredients for good ERA

For a successful ecological risk assessment project, an early clarification of the objectives of ERA is essential. One needs to develop a good conceptual model that includes all potential/broad compartments and that can provide a context for individual team members of the project team. Often a template methodology can help avoid systematic errors. An ongoing validation/review of the conceptual model is essential. ERA is multidisciplinary by its very nature and therefore a proper integration of the different components is essential.

5. *For a successful ERA application of ERA, it is essential to have a good conceptual model and detailed plan, early stakeholder (e.g. community, policy makers and regulators) involvement, a highly skilled multidisciplinary team and an effective project leader with a broad skill-base.*

Interpretation of ecotoxicological data to determine the acceptable level of risk

The species of concern in an ERA (i.e. what is being protected) and the ecotoxicological endpoints chosen are probably the two factors that are crucial for appropriate interpretation of the ecotoxicological data. Our current lack of understanding of ecosystem functions and other limitations, such as ability to predict at the broad process level but not at the species level, present challenges. Currently toxicity tests more often focus on mortality than on the physiological and ecological functions but this needs to change.

6. *There are considerable difficulties in interpretation of mortality based ecotoxicological data in relation to ecosystem functions and more robust approaches are needed. Standardisation of protocols and guidance on this aspect are needed.*

Inclusion of bioavailability in ERA

There is a growing recognition of the need to include bioavailability aspects in risk assessment, despite the fact that considerable data are published on bioavailability of metals and to a lesser extent on organic contaminants in terrestrial ecosystems. In the Netherlands, normalization of data is being used to allow for bioavailability input. However, the bioavailability concept remains fairly ambiguous to stakeholders and it means different things to different people (Faber 2005). The desire to include bioavailability assessment in ERA is further hampered by limited availability of information and uncertainty about the quality of the available data. There are no standard methods of assessing bioavailability and no database is currently available, at least in Australia.

7. *Development of Environmental Investigation Levels (EILs) incorporating bioavailability for a limited number of metals and organic compounds is highly desirable, to serve a as useful model for the future. Standard protocols and bioavailability database should be developed.*

Dealing with randomness (stochasticity), data deficiency (ignorance) and mistakes in assessment (errors) and the accumulation of errors

Uncertainty is at the very core of the multidisciplinary framework of ERA. Sources of uncertainty are be many and varied. As described by Beer (2005, this volume), it can arise from the natural randomness of data (aleatory uncertainty) and/or imperfect knowledge and information (epistemic uncertainty). It is therefore essential to adequately recognise limitations of different approaches and the degree of uncertainty associated with the assessment. The degree of uncertainty not only needs to be properly assessed but also needs to be explicitly communicated (USEPA 2004).

3. *Aleatory uncertainty needs to be reduced as much as possible by choosing appropriate tools and techniques. Both the aleatory and epistemic uncertainty must be properly quantified and explicitly communicated in risk based decision-making process*.

Statistical techniques and packages to deal with uncertainty/sensitivity

Statistical tools and techniques (of varying degree of complexity) are increasingly being used for characterising and dealing with uncertainty. Some of the common techniques to address measurement error and variability include scenario (near worst-case) analysis, interval arithmetic, fuzzy arithmetic, Monte Carlo analysis and probability bounds analysis. Probabilistic techniques like Monte Carlo analysis are increasingly being favoured (USEPA 1997), because these allow the assessment of relationships between risk and input variables and the investigation of the effects of different assumptions during risk assessment.

User-friendly packages are available that enable Monte Carlo simulations to be undertaken readily. One of the best known packages is @risk (www.palisade.com) . This package can be implemented as an add-on to Excel. This means that any model that can be written in Excel can be easily turned into a Monte Carlo simulation.

8. *Emphasis should be placed on choosing the appropriate programming tool consistent with the desired quality of output. Where possible, simulations should be undertaken using standard software so that the stakeholders can readily repeat the results.*

Adopting/ adapting international standards

Various approaches are being used around the world, e.g. target or threshold values for contaminants in soils versus broader risk framework approach. If one uses International Standards or guidelines – the key question is if the protection provided in relevant and adequate to site where it is being applied. The Australian terrestrial environment is different, say for example, from the European environment. Ants and termites are, for example, the key soil engineers in Australian terrestrial ecosystems, whereas earthworms are more relevant to European ecosystems. Therefore, an international guideline may not provide adequate protection to the unique flora and fauna (e.g. marsupials) of Australia because they are based on inappropriate species. However, even if there are similar organisms in Australian and European ecosystems differences in the sensitivity of the organisms could lead to international guidelines providing inappropriate protection. This issue of whether there are differences in sensitivity between Australian, North American and European aquatic species is currently being addressed (see Hobbs *et al*. 2004) There is an opportunity for Australia to develop locally relevant tests that can also contribute to the international arena.

9. *The overseas risk standards, such as in European Union, may not directly applicable to Australia and therefore these need to adapted for local conditions. Site-specific risk assessment needs a degree of customization to the site as well as there has to be room to tailor-make parameters and criteria, arising from consultations with stakeholders.*

Risk Communication

Risk based approaches often fail due to poor communication. Communication in ERA is essential at a range of levels: such as within-team, with stakeholders and with the community. It needs to be recognized that community concerns and emotions are valid: even when they may be out of proportion. Adequate resources need to be allocated to develop trust and collaboration with the local community. “Stakeholder fatigue” is an emerging concern that ERA practitioners need to be aware of in the communication process (see for example http://www.buseco.monash.edu.au/units/mesrru/about.php.)

10. *Early engagement of stakeholders and transparency of all steps in the process should be a priority because in most cases this enables the stakeholders a sense of ownership of the problem.*

Concluding remarks

Within the broader context of cost-benefit analysis, ERA is seen to be a attractive tool for management of chemicals and contaminants in terrestrial ecosystems. While several agencies currently use ERA as a decision making tool in Australia, there is a general consensus that there is need to develop standard protocols and guidelines to provide a consistent framework for use by specialists in this area.

The National Environment Protection Council agreed in December 2004 to commence a review of the NEPM for the Assessment of Site Contamination, and this review will provide an opportunity to further develop the guidelines for ERA and facilitate greater utilisation of ERA as a tool. It is hoped that some of the outcome of the workshop will not only contribute to the review process, but also result in enhanced understanding of ERA and facilitate interactions among the stakeholders who participated in the workshop.

Acknowledgments

The authors acknowledge the useful comments made to this manuscript by Dr Bruce Kennedy and Dr Michael Warne. Figure 1 was provided by the National Environmental Protection Council.

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