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# Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA)

**Final report**

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German National Research Centre for Environment and Health (DE)


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| **Dissemination level** | | |
| **PU** | Public | X |
| **RE** | Restricted to a group specified by the partners of the project | |
| **CO** | Confidential, only for partners of the project | |

# Introduction

The ERICA project was partly funded by the EU under the Sixth Euratom Framework Programme (FP6 Euratom). It brought together over 50 scientists from 15 organisations and 7 countries. ERICA was designed to support efforts to assess the environmental impact of ionising radiation and to protect the environment from harmful effects of ionising radiation. The project continued and broadened the earlier FASSET (Framework for Assessment of Environmental Impact) and EPIC (Environmental Protection from Ionising Contaminants in the Arctic) projects, supported under FP5 Euratom. The work paralleled the work of the International Commission of Radiological Protection (ICRP) in the area and there were frequent contacts and collaboration between the ERICA project and other international and national programmes in the field of environmental radioactivity.

# Objectives

The objective of ERICA was to provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation, with emphasis on biota and ecosystems. The final outcome of the project is the ERICA *integrated approach to assessment and management of environmental risks from ionising radiation*, using practical tools.

The ERICA project started in March 2004 and was divided into five work packages (WPs). The ERICA integrated approach was delivered at the end of the project, in February 2007. The specific objectives of each WP are set below and their inter-relationships illustrated in Figure 1.

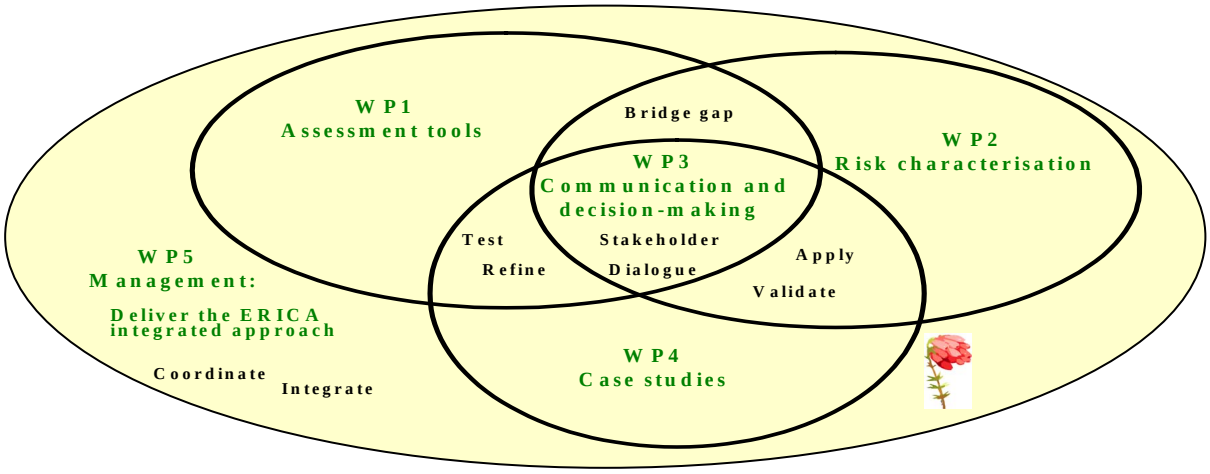


**Figure 1:** Schematic representation of the ERICA project (2004-2007) and the integration of work packages to produce the integrated approach

WP1 – **to provide an assessment tool**, achieved through targeted theoretical studies that enhance the quality and robustness of the assessment methodology as well as feed scientific knowledge into the other WPs.

WP2 – **to provide risk characterisation methodologies for ecologically meaningful estimates of risk**. This was achieved through taking into account knowledge developed under WPs 1, 3 and 4 and by theoretical considerations of extrapolation and scaling issues. Some of these issues associated with methods conceived to do with the unknown were scientifically supported by targeted experimental studies.

WP3 – **to provide managerial guidance together with stakeholder involvement, to support the protection of the environment from ionising radiation**. This WP brought together the scientific assessment tool (WP1) and risk characterisation (WP2), and the developed integrated approach tested in case studies (WP4). The work relied to a great extent on an end-users group (EUG) established under the project, where a number of stakeholder dialogue methodologies were used to gather information based on end-users' experience, expertise and opinion.

WP4 – **to apply and test, in case-study scenarios for different sites, the assessment methodologies**. The WP considered methodologies developed both under the FASSET project and the integrated approach developed under ERICA, providing feedback on data gaps and problems needing consideration in ERICA.

WP5 – **to provide the general management and progress assessment to the project**. The WP aimed at managing the ERICA project and assessing its progress, and to deliver the integrated approach as described in the final deliverable of the project, D-ERICA.

# Development of the project

## Definition of tiers to guide assessment and decision-making (WP2 in conjunction with WPs 1, 3 and 4, and with the end-users group)

From early on, the consortium in communication with the end-users group (EUG) agreed on a tiered approach to guide assessment, risk characterisation and managerial decisions, including the interaction with stakeholders. The core of this approach is summarised in Figure 1. Starting from the problem formulation and scope, Tier 1 corresponds to a risk-screening exercise. Tier 2 is a refined Tier 1 in terms of exposure analysis. Tiers 1 and 2 use the so-called *predicted no-effect dose rate* (PNEDR in µGy/h), derived from knowledge on radionuclide effects on non-human species. Tier 1 proposes a back-calculation of corresponding screening values – the *environment media limiting concentrations* (EMCLs) expressed in Bq/l or Bq/kg for the main media (i.e. water, sediment, soil, air) and for each radionuclide. For a given radionuclide, these screening values (one per medium) correspond to the minimum value among all back calculations, on the PNEDR basis, for all reference organisms. At Tier 2, the PNEDR is used directly and is compared to the calculated dose rate for the set of reference organisms. Tier 3 proposes the use of site-specific data and probabilistic methods to calculate the risk of harmful effects resulting from presence of ionising contaminants.

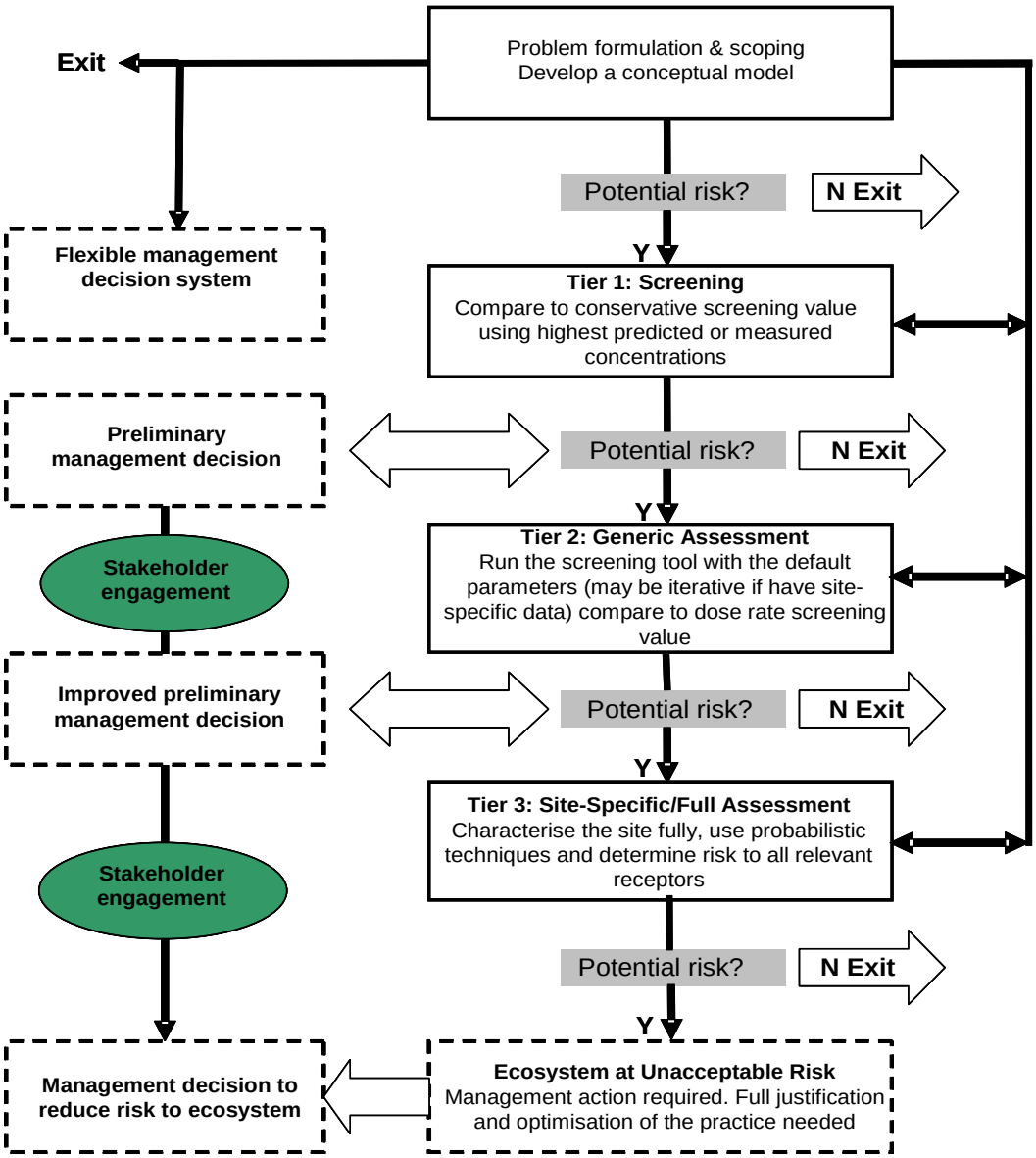


**Figure 1:** Overview of the ERICA tiers

## The ERICA tool (WP1)

WP1 developed the assessment tool including the incorporation of ecosystem- and organism-specific parameters. The tool was available as a prototype for the last two years of the project, being continuously improved and receiving comments from both inside and outside the consortium. WP1 also further developed the FASSET Radiation Effect Database (FRED) by incorporating data from other sources, e.g. the EPIC project; by incorporating new data; and by quality-checking all the existing data in FRED. The resulting improved dose-effect database became known as FREDERICA. The prototype, updated regularly, was posted on the ERICA website for testing by both consortium partners and members of the EUG.

## Risk characterisation (WP2)

WP2 worked on three sub-tasks, each corresponding to a deliverable: risk characterisation methodologies; extrapolation issues including supporting experimentation; and development of good practice guidance. The derivation of predicted no-effect dose-rate values for ecosystems and their sub-organisational levels exposed to radioactive substances underpinned the development of the ERICA tool.

Experiments on daphnia and earthworms have been used to illustrate the method to take individual-to-population extrapolations into account.

## Decision-making and interaction with stakeholders (WP3)

The end-users group (EUG) was created with 52 international and national organisations from Europe, Australia, Canada, Japan, and the USA. The EUG was composed of regulators, academia, industry, NGOs, and inter-governmental organisations. This forum enabled the project to host eight events to discuss issues based on specific themes, including assessment frameworks and scientific knowledge gaps; ionising radiation and other contaminants; decision-making and stakeholder involvement; scientific uncertainties; a consensus seminar; management, compliance and demonstration; an ERICA tool testing day; and a local stakeholder event. WP3 in conjunction with WP 1 organised a one-day workshop with the EUG to test the ERICA tool and developed a training pack for the ERICA Open Event, organised in Paris, February 2007.

WP3 also developed the deliverable D8 relating to decision-making and options to be considered at the formulation stage, which will impact on the scope of the assessment.

## Case studies (WP4)

The FASSET methodology was tested on five case studies, including the Loire River (receiving discharges from five nuclear installations including 13 power reactors); marine oil rigs discharging natural alpha-emitting nuclides; areas in the Komi Republic of the Russian Federation with elevated levels of natural radionuclides; the Sellafield terrestrial environment and the Chernobyl exclusion zone. Work continued through the gathering of additional site data required prior to testing and validating the ERICA integrated approach and the ERICA tool on the case studies (note that the oil rig case was dropped and replaced with Drigg sand dunes and coastal environment).

Much of the feedback from the case-study applications identified parts of the integrated approach that were poorly explained. As a consequence, both D-ERICA and the tool help file were extensively rewritten.

## The ERICA integrated approach (WP5 in conjunction with all other WPs) – an overview

The purpose of the *ERICA integrated approach* is to ensure that decisions on environmental issues give appropriate weight to the environmental exposure, effects and risks from ionising radiation with emphasis on ensuring the structure and function of ecosystems. To fulfil this objective, elements related to environmental management, risk characterisation and impact assessment have been integrated (hence the *integrated approach*) into one common structure, illustrated in Figure 2.

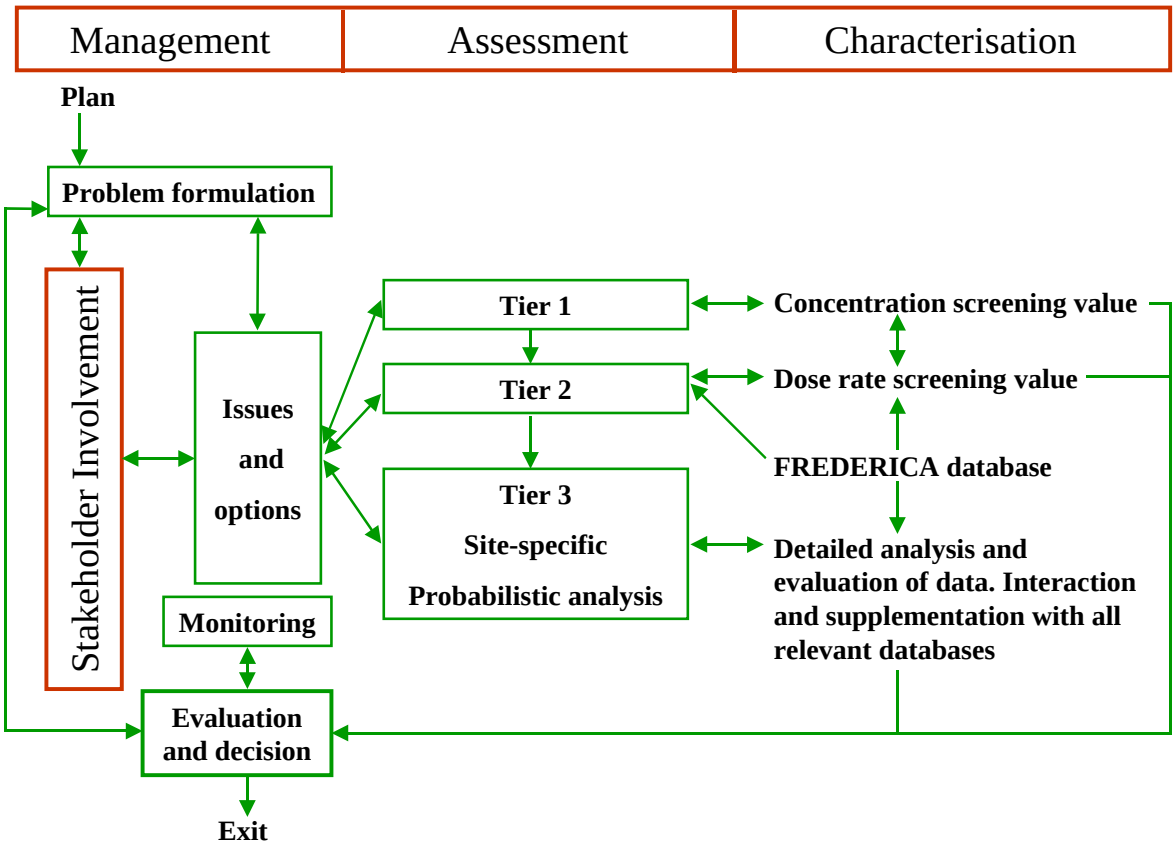


**Figure 2:** Structure of the ERICA integrated approach, depicting its three main integrated features: an assessment tool, a methodology for risk characterisation, and guidance to stakeholder involvement and decision-making (management)

*Assessment* refers to the process of estimating exposure of biota, which involves estimating or measuring activity concentrations in environmental media and organisms, defining exposure conditions, and estimating radiation dose rates to selected biota.
*Characterisation* includes estimation of the probability and magnitude of adverse effects in biota, together with identification of uncertainties. Within the ERICA integrated approach, published effects data are used as the basis of the assessment, with risk characterisation performed by evaluating the output data from the assessment (estimates of exposure) against an effects analysis.
*Management* is used here as a general term for the process of taking decisions before, during, and after assessment. The term covers such diverse aspects as decisions on specific technical issues associated with the execution of the assessment, general decisions relating to the interaction with stakeholders, and post-assessment decisions.

## *Using the ERICA integrated approach*

The ERICA integrated approach advises the user on how to formulate the problem (involving stakeholders if appropriate), perform an impact assessment, and evaluate data. It outlines the issues and options available to the user (and requiring decisions) before, during, and after assessment.

The ERICA integrated approach is supported by the *ERICA tool*, which is a software programme that guides the user through the assessment process, keeps records, and performs the necessary calculations to estimate dose rates to selected biota. A detailed help is provided to assist the user in making appropriate choices and inputs, as well as interpret the outputs. The tool interacts with a number of databases and other functions that help the assessor to estimate environmental media activity concentrations, activity concentrations in biota, and dose rates to biota. The databases consider the majority of the radionuclides included in Publication 38 of the International Commission on

Radiological Protection (ICRP). The ERICA tool also interfaces with the FREDERICA radiation effects database, which is a compilation of the scientific literature on radiation effect experiments and field studies, organised around different wildlife groups and, for most data, broadly categorised according to four effect umbrella end points: morbidity, mortality, reproduction, and mutation.

The databases of the ERICA tool are built up around a number of reference organisms. Each reference organism has its own specified geometry and is representative of either terrestrial, freshwater or marine ecosystems. The approach is compatible with that used by ICRP; some of the geometries proposed for the ICRP 'reference animals and plants' are used as defaults in the ERICA tool.

The assessment element of the ERICA integrated approach is organised in three separate *tiers*, where satisfying certain criteria in Tiers 1 and 2 allows the user to exit the assessment process while being confident that the effects on biota are low or negligible and that the situation requires no further action. Where the effects are not shown to be negligible, the assessment should continue to Tiers 2 and 3. Situations of concern should be assessed further in Tier 3, by making full use of all relevant information available through the integrated approach or elsewhere.

### *Formulating the problem and interacting with stakeholders*

*Problem formulation* is the first step of any risk assessment and includes consideration of ecological, political and societal issues when deciding on procedures and methods, who to involve, and any benchmarks or assessment criteria that the outcome will be compared to. Problem formulation also represents the first stage of the assessment where an assessor might exit the process. A decision *not* to proceed might be made on technical grounds (for example, no direct exposure route) or societal grounds (such as a veto on the discharge of radionuclides regardless of risks to biota). Stakeholder participation procedures vary and there is no single procedure or group of stakeholders that is likely to suit each purpose. In practice, and if participation is deemed important to a decision, a variety of methods are likely to be adopted.

The problem formulation and participation procedures may largely be regulated by legislation. The ERICA integrated approach provides information and advice for complying with such legislation and lists additional elements to consider should the user wish to do so. In the process of coming to a decision the problem may need to be re-formulated several times, with the involvement of stakeholders if appropriate, in the light of new information as the assessment proceeds. The ERICA tool helps the user to consider relevant aspects and record decisions taken with regard to these issues.

### *Tier 1 assessment*

The Tier 1 assessment is designed to be simple and conservative, requiring a minimum of input data and enabling the user to exit the process and exempt the situation from further evaluation, provided the assessment meets a predefined screening criterion. The default screening criterion in the ERICA integrated approach is an *incremental dose rate of 10 μGy* $h^{-1}$, to be used for all ecosystems and organisms. This value was derived from a species sensitivity distribution analysis performed on chronic exposure data in the FREDERICA database and is supported by other methods for determining predicted no-effect values. However, the user can change the default screening dose rate within the ERICA tool. For Tier 1, the predefined screening dose rate is back-calculated to yield environmental media concentration limits (EMCLs) for all reference organism/radionuclide combinations. The tool compares the input media concentrations with the most restrictive EMCL for each radionuclide and determines a risk quotient (RQ). If the RQ is less than one, then the tool suggests that the user should exit the assessment process. If the RQ is greater than one, the user is advised to continue with the assessment.

### *Tier 2 assessment*

Tier 2 allows the user to be more interactive, to change the default parameters, and to select specific reference organisms. The evaluation is performed directly against the screening dose rate, with the dose rate and RQs generated for each reference organism selected for assessment. A 'traffic light' system is used to indicate whether the situation can be considered

(i) of negligible concern (with a high degree of confidence);
(ii) of potential concern, where more qualified judgements may need to be made and/or a refined assessment at Tier 2 or an in-depth assessment in Tier 3 performed;
(iii) of concern, where the user is recommended to continue the assessment either at Tier 2, if refined input data can be obtained, or at Tier 3.

Decisions to exit an assessment given outcomes (ii) and (iii) should be justified, for example by using information from FREDERICA provided in the tool as 'look-up effects tables' for different wildlife groups.

### *Tier 3 assessment*

Situations which give rise to a Tier 3 assessment are likely to be complex and unique. It is therefore not possible to provide detailed or specific guidance on how the Tier 3 assessment should be conducted. Furthermore, a Tier 3 assessment does not provide a simple yes/no answer nor is the ERICA-derived incremental screening dose rate of 10 $\mu Gy\ h^{-1}$ appropriate with respect to the assessment end point. The requirement to consider aspects such as the biological effects data within the FREDERICA database or to undertake ecological survey work is not straightforward and requires an experienced, knowledgeable assessor or consultation of an appropriate expert.

Tier 3 is a probabilistic risk assessment in which uncertainties within the results may be determined using sensitivity analysis. The assessor can also access up-to-date scientific literature (which may not be available at Tier 2) on the biological effects of exposure to ionising radiation in a number of different species. Together, these allow the user to estimate the probability (or incidence) and magnitude (or severity) of the environmental effects likely to occur and, by discussion and agreement with stakeholders, to determine the acceptability of the risk to non-human species.

### *Post-assessment considerations*

Since the aim of the ERICA integrated approach is to aid decision-making so that adequate weight is given to the environmental effects of ionising radiation, the integrated approach is non-prescriptive and does not specify decisions that *must* be taken. This flexibility is necessary because of the diversity of environmental legislation. Nevertheless, the integrated approach offers guidance on a number of issues and options and a structure for reaching a decision. However, a decision taken to justify exiting the assessment may not necessarily conclude the process. In most cases, where a decision has been taken via a full Tier 3 assessment, this may have to be revisited regularly on the basis of new information or as part of licensing conditions.

# Dissemination

The ERICA e-newsletters were produced regularly to inform stakeholders of project progress and seek views on WP issues. The ERICA project produced a number of deliverables during the lifetime of the three-year project, as listed below[1].

| | |
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| **D1** | Copplestone, D (ed.) (2005): Progress on the production of the web-based effects database: FREDERICA. ERICA Deliverable D1.EC contract N° FI6R-CT-2004-508847 |
| **D2** | The prototype of the ERICA tool (2006). Available on www.erica-project.org. To be replaced by the final version of the ERICA tool in February 2007, on the same website. EC contract N° FI6R-CT-2004-508847 |
| **D4a** | Copplestone D, Björk M and Gilek M (eds) (2005): Ecological risk characterisation: An interim method for the ERICA integrated approach. ERICA Deliverable D4a. EC project contract N° FI6R-CT-2004-508847 |
| **D4b** | Björk M and Gilek M (eds) (2005): Overview of ecological risk characterisation methodologies. ERICA Deliverable D4b. EC project contract N° FI6R-CT-2004-508847 |
| **D5** | Garnier-Laplace J and Gilbin R (eds) (2006): Derivation of predicted no-effect dose-rates values for ecosystems and their sub-organisational level exposed to radioactive substances. ERICA Deliverable D5. EC project contract N° FI6R-CT-2004-508847 |
| **D5 Annex A** | Garnier-Laplace J and Gilbin R (eds) (2006): Guidelines for the design and statistical analysis of experiments on chronic effects of radioactive substances. ERICA Deliverable D5, Annex B – public. EC project contract N° FI6R-CT-2004-508847 |
| **D5 Annex B** | Gilbin R and Oughton D (eds) (2006): Experiments on chronic exposure to radionuclides and induced biological effects on two invertebrates (earthworm and daphnia). Results and discussion. ERICA Deliverable D5, Annex B – public. EC project contract N° FI6R-CT-2004-508847 |
| **D7a Part 1** | Oughton D, Zinger I, Bay I, Børretzen P, Garnier-Laplace J, Larsson CM and Howard B (2004): First EUG event – Part 1: Discussion of ERICA work plan. ERICA Deliverable D7a – Part 1. EC project contract N° FI6R-CT-2004-508847 |
| **D7a Part 2** | Oughton D, Zinger I, Bay I and Larsson CM (2004): First EUG event – Part 2: Briefing notes on assessment frameworks and knowledge gaps. ERICA Deliverable D7a – Part 2. EC project contract N° FI6R-CT-2004-508847 |
| **D7b** | Oughton D, Zinger I and Bay I (2004): Briefing notes from the second thematic EUG event. Part 1: Ionising radiation and other contaminants, and Part 2: Contribution to deliverable D4 on risk characterisation. ERICA Deliverable D7b. EC project contract N° FI6R-CT-2004-508847 |
| **D7c** | Zinger I (ed.) (2005): Transcripts from the first generic EUG event: Ecological risk assessment and management. ERICA Deliverable D7c. EC project contract N° FI6R-CT-2004-508847 |
| **D7c Annex 1** | Zinger I (ed.) (2005) Added written comments from the Freising questionnaire. ERICA Deliverable D7c Annex 1. EC project contract N°FI6R-CT-2004-508847 |
| **D7d** | Copplestone D, Zinger I and Oughton D (eds) (2005): Transcript from the third thematic EUG event: Decision-making and stakeholder involvement. ERICA Deliverable D7d. EC project contract N° FI6R-CT-2004-508847 |
| **D7e** | Oughton D and Breivik H (eds) (2005): Scientific uncertainties: Transcript from the EUG workshop. ERICA Deliverable D7d. EC project contract N° FI6R-CT-2004-508847 |
| **D7f** | Forsberg ME and Oughton D (eds) (2006): The ERICA consensus seminar. ERICA Deliverable D7f. EC project contract N° FI6R-CT-2004-508847 |
| **Consensus document** | Consensus document (2006): EUG Event – Stavern, June 2006. EC project contract N° FI6R-CT-2004-508847 |
| **D7g** | Zinger I, Vetikko V, Sjöblom KL, Jones S, Hubbard L, Copplestone D, Michalik B, Prlic I and Momal P (2007): Summary of the EUG event on management, compliance, and demonstration. Deliverable D7g. EC project contract N° FI6R-CT-2004-508847 |
| **D7h** | Zinger I (ed.) (2007): EUG tool testing event. Deliverable D7h. EC project contract N° FI6R-CT-2004-508847 |

[1] Note that the original plan to publish three additional deliverables, D3, D6 and D11, was abandoned in favour of publication of the comprehensive deliverable ERICA, referred to as D-ERICA.

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| **D7i** | Jones S (ed.) (2007): Local stakeholder EUG event. Deliverable D7i. EC project contract N° FI6R-CT-2004-508847 |
| **D7 total** | Zinger I and Oughton D (ed.) (2007): Summary of all ERICA EUG events. EC project contract N° FI6R-CT-2004-508847 |
| **D8** | Zinger I, Copplestone D, Brown J, Sjöblom KL, Jones S, Pröhl G, Oughton D and Garnier-Laplace J (2007): Considerations for applying the ERICA integrated approach. Deliverable D8. EC project contract N° FI6R-CT-2004-508847 |
| **D8 Annex A** | Copplestone D (ed.) (2007): Review of international legal instruments that may influence decision-making. Deliverable D8 Annex A. EC project contract N°FI6R-CT-2004-508847 |
| **D9** | Beresford NA and Howard B (eds) (2005): Application of FASSET framework at case-study sites. Deliverable 9. EC project contract N° FI6R-CT-2004-508847 |
| **D10** | Beresford NA, Howard BJ and Barnett CL (2007): Application of ERICA integrated approach at case-study sites. EC project contract N° FI6R-CT-2004-508847 |
| **D-ERICA** | Beresford NA, Brown J, Copplestone D, Garnier-Laplace J, Howard B, Larsson CM, Oughton D, Pröhl G and Zinger I (eds) (2007): An integrated approach to the assessment and management of environmental risks from ionising radiation. Description of purpose, methodology and application. EC project contract N° FI6R-CT-2004-508847 |
| **D-ERICA Annex A** | Copplestone D (ed.) (2007): Uncertainty matrix applicable to the ERICA tool. EC project contract N° FI6R-CT-2004-508847 |
| **D-ERICA Annex B** | Copplestone D and Zinger I (eds) (2007): Glossary. EC project contract N° FI6R-CT-2004-508847 |

All deliverables from ERICA, including the ERICA tool and FREDERICA, can be freely downloaded from the ERICA website: www.erica-project.org.

A special issue of *Journal of Environmental Radioactivity* is being planned for 2008. It will highlight some of the work carried out as part of the ERICA project. In addition, a substantial number of papers based on the ERICA project have appeared in the scientific literature.

An agreement between the consortium partners is being developed so that further developments of the ERICA tool and its databases are pursued until at least 2010. D-ERICA will also be updated if deemed necessary, following the changes to the tool or its databases.

# Implications

The full impact of the ERICA project is presently hard to assess. However, it is the most recent and extensive completed collaborative scientific project in the field. The project has laid a foundation for the current Euratom PROTECT project. Furthermore, the methodology and databases have heavily influenced the current activities of ICRP, notably the work on reference animals and plants currently carried out within ICRP's Committee 5.

FASSET and ERICA, together with EPIC and other projects, have thus provided an extensive documentation of the scientific basis for environmental radiation protection, extended the knowledge base, and also arranged available data in a manner that supports decision-making. The integration of this knowledge in international and national regulatory frameworks is presently dependent on the interest (or non-interest) of policy-makers and higher levels of the political hierarchy to do so. Those supporting such integration see it as a valuable tool to, *inter alia:*

- prioritise actions;
- facilitate stakeholder interactions;
- provide 'additional lines of reasoning' when building safety cases for e.g. repositories for high-level waste; and
- avoid rejection of technically sound projects due to lack of evidence for them being 'environmentally safe', thus saving societal resources.

Those opposed generally refer to the earlier ICRP doctrine (that non-human species are adequately protected under circumstances where humans are protected) as valid and any further considerations of the environmental implications of radiation as non-justified and wasting resources that would be better spent elsewhere.

It is impossible to foresee what course(s) this debate will take. However, ERICA may help bridge the gap between the opposing views described above, as the ERICA integrated approach effectively screens out situations of no concern and assists decision-making where there is concern, thus allowing for proportionate actions which should serve the interests of all concerned parties.

# Acknowledgements

The ERICA project was supported by the Sixth Euratom Framework Programme (2002-2006). The financial support of the EU is gratefully acknowledged. More information on the EU research and training programme Nuclear Fission and Radiation Protection can be found on:
http://www.cordis.lu/fp6-euratom/home.html