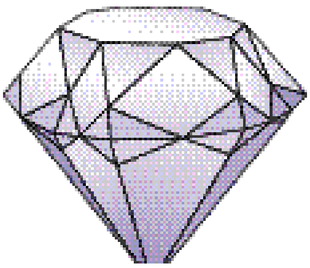
# ANNEX I
# DESCRIPTION OF WORK

# Framework for Assessment of Environmental Impact

# FASSET



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| Project Coordinator: | Swedish Radiation Protection Institute |

Contractors:

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| Swedish Radiation Protection Institute | SSI |
| Swedish Nuclear Fuel and Waste Management Co. | SKB |
| Environment Agency of England and Wales | EA |
| German Federal Office for Radiation Protection | BfS |
| German National Centre for Environment and Health | GSF |
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# Summary

FASSET will bring to radiation protection a framework for the assessment of environmental impact, i.e. impacts on organisms and ecosystem processes. These issues are presently rarely being addressed in radiation protection, and other environmental management systems do not address radiation protection issues. The framework will link together current knowledge about sources, exposure, dosimetry and environmental effects/consequences, by providing a reference set of models, for target organisms and ecosystems. Relevant components of the framework will be identified on an ecosystem basis through systematic consideration of the available data and expert judgement.

FASSET will produce a framework for assessment of environmental impact, with a focus on non-human biota and ecosystem function. This will be achieved through the exchange of experience gained in four work packages. These set out to identify target organisms in terrestrial and aquatic ecosystems of Europe and to develop corresponding dosimetric models (WP 1), to use ecosystem-based approaches to identify critical internal and external exposure situations and corresponding models (WP 2), to identify critical effects and biological organisation levels of concern (WP 3), and to link these components into a framework, taking account of, inter alia, existing frameworks for managing risks from other pollutants (WP 4). The development of the framework will necessitate substantial communication between WPs 1-3, supported by development of a generic framework in WP 4. The final product, the framework for assessment of environmental impact from radiation, will be produced within WP 4, based on synthesis of information from all other workpackages.

A sequence of workshops will be organised, in which the work within the work-packages will be planned, discussed, scrutinised, and co-ordinated. Tentatively, these workshops will take place at 0, 6, 18, 24, 30 and 36 months. A total number of six main reports for public dissemination will be published, including the final report on integration of all findings to produce the framework for assessment of environmental impact.

The framework will contain a reference set of models, including exposure (internal and external) models, and dosimetric models in which Monte Carlo methods will have to be used to derive dose coefficients, and in which the issue of relevant weighting factors for different kinds of radiation will be taken into account. It will also include a summary of the effects of chronic irradiation on the endpoints determined to be of significance for the target organisms in an environmental context. The reference sets will be developed on the basis of target organisms occupying generic ecosystems, taking into account the diversity of European natural and semi-natural environments. In the identification of relevant elements, expert judgements will be made. The justification and limitation of applicability of the reference sets will be assessed.

The framework will be a useful tool for assessing environmental impact, judging compliance against environmental quality criteria and standards, and communicating to different stake-holders the likely environmental consequences of projects in a planning stage.

The work is relevant to Community environmental and life quality. It also contributes to our understanding and implementation of sustainability in the use of natural resources. It relates directly to the communication with stake-holders concerned with environmental issues within impact assessments, which is particularly relevant for several Union members with major nuclear programmes and on-going proposals for the siting of spent fuel repositories.

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# 1. Objectives.

The requirement for assessments of the environmental effects of radiation is increasing due both to growing public awareness and concern for environmental protection issues and to the evolving integration of environmental impact assessments into the regulatory process. Thus, there is a strong momentum to establish a framework for protection of the environment from ionising radiation. A well-defined and agreed framework would be of benefit to both regulators and to organisations responsible for the development, implementation and operation of nuclear facilities, and would help in decision-making on these issues and in the setting of standards for environmental protection. Such a framework would, in addition, help to make a clear and understandable presentation of the environmental effects assessment to members of the public.

## *1.1 Background*

That there is an increasing need for such an assessment framework is shown in the following summary of recent developments in the field of environmental radiation protection. It is an obvious fact that the well being of humans is dependent on the well being of the environment, including the organisms that together with humans inhabit the environment. Most attention in radiation protection has, however, been given to the protection of humans alone. This has been justified from a historical point of view and contributed to a high level of protection of workers, patients and the general public against the detrimental effects of radiation. At the same time, progress in risk reduction is characterised by a gradual shift in focus along the sequence: protection of workers – protection of the general public – product and practice safety – environmental protection. Accordingly, provisions on protection of the environment from harmful effects of radiation are now being included in national legislation in several countries.

Internationally, radiation and/or radioactive waste is addressed in conventions on environmental protection. For example, management of radioactive substances has recently been the subject for the formulation of a specific strategy within the OSPAR Convention for Protection of the Marine Environment of the Northeast Atlantic. Conversely, environmental protection is specifically addressed in conventions on waste safety, e.g. the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The second principle of the IAEA Safety Fundamentals for the Management of Radioactive Waste, "*Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment*", applies directly to environmental protection (see also in the OECD/NEA 1995 Collective Opinion on the Environmental and Ethical Basis of geological disposal).

Several relevant documents have emerged from the 1992 UNCED Earth Summit in which a number of general principles for environmental protection have been laid down. Examples of these documents are the Rio Declaration, the Convention on Biological Diversity, and the work-programme, Agenda 21. In different ways these documents bear on radiation protection from an environmental perspective. The Rio Declaration [UNCED 1992a] emphasises in Principle 4 the issue of sustainable development[1], stating that development should take place with proper consideration of the use and maintenance of resources. Environmental protection

[1] UNCED definition: 'use of biological components of biological diversity in a way and at a rate that does not lead to the long-term decline in biological diversity, thereby maintaining its potential to meet the demands of present and future generations.

shall constitute an integral part of the development process and cannot be considered in isolation from it.

Public awareness and concern is growing in this area, and environmental protection issues constitute integral parts of environmental impact assessments (EIAs), involving consultation procedures, reviews, inquiries, etc., as well as of environmental impact statements (EISs; see also Principles 10, 17 and 22 of the Rio Declaration). Demands for EIA are specified in the EU legislation (e.g. Council Directives 85/337 and 97/11). Furthermore, installations that are of concern in a transboundary context have to be reviewed in accordance with the provisions of Article 37 of the Euratom Treaty. Also the Espoo Convention on Environmental Impact Assessments in a Transboundary Context applies in this situation.

In a recent publication, the International Atomic Energy Agency reviewed a number of international approaches to environmental radiation protection, as well as the approaches, criteria, and regulations currently being implemented in 12 IAEA member states [IAEA 1999]. The majority of these states applies the ICRP (International Commission on Radiological Protection) approach, or develops approaches that are consistent with the ICRP approach. At the same time, the current position of the ICRP, as laid down in the last versions of the recommendations [ICRP 1991] is that *"…. The Commission believes that the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk. …… At the present time, the Commission concerns itself with mankind's environment only with regard to transfer of radionuclides through the environment, since this directly affects the radiological protection of man."*

The ICRP is in the process of reviewing its recommendations, which includes its position on environmental protection and a specific working party has been set up. However, presently there is no agreed framework within which environmental consequences (other than human health effects) are assessed and managed.

## *1.2 Project objectives*

The main objective of the proposed project is to create a framework for assessing the impact of radioactive contamination on the environment. The framework will provide a system for linking together the release scenario, exposure pathways, dose to biota and effects at different levels of biological organisation. An important part of the project task will be to identify what is critical and relevant, based on our current scientific understanding, and identify the major uncertainties. A further task will be to limit the assessment to reference sets of, for example, exposure scenarios, target organisms, biological end-points, and to clearly justify these limitations. When developed, the framework will be applicable to both chronic and accident situations.

The project has the following practical objectives:

- To provide a reference set of critical target organisms relevant to different exposure situations. The identification of critical target organisms must take into account the environmental fate of radionuclide releases, exposure pathways, dosimetry and biological effects. A sound justification will be given for the choices made.
- To provide a set of reference models for the critical target organisms, including models for environmental transport of radionuclides, exposure of the critical target organisms, dosimetry and biological effects. The reference models will be accompanied by generic databases designed to act as sources of data for critical target organisms in different exposure situations.

- To critically examine the level at which protective action should be directed (the population, ecosystem, biodiversity etc.) taking due account of the available knowledge concerning the biological effects of radiation and using a systems ecology approach to the identification of important ecosystem processes.
- To review existing frameworks for environmental assessment used in different environmental management or protection programmes. This review will extend outside the field of radiation protection, where such schemes are presently scarce, and consider, *inter alia*, frameworks for managing risks from genotoxic chemicals. The framework developed within this project will thus be set in a wider context of assessments of environmental effects and management of risks to the environment.

The project aims to take a practical approach to assessment and reduction of detrimental environmental effects. The framework will be based mainly on currently existing models and techniques, though some techniques will be applied in new contexts and some new developments will be made in well-defined areas. The idea is to present an overview of current knowledge, structured in a logical way and based on a sound scientific understanding.

The achievement of the project objectives can be verified when the following deliverables have been completed:

- A report reviewing existing programmes for environmental assessment and management of environmental risks from ionising radiation and hazardous chemicals.
- A report defining sets of generic fauna and flora that are appropriate to the marine, freshwater and terrestrial environments of Europe. The target organisms will be identified on the basis of interaction matrices representing the transfer of radionuclides in the relevant exposure pathways for selected release scenarios.
- The development of corresponding radiation dosimetry models for the selected target organisms. These models will be used to tabulate absorbed dose rate coefficients (Gy/s per unit radionuclide concentration in the relevant environmental compartment) for each target organism and the major radionuclides of concern.
- A report providing a justification of the level of biological hierarchy to be protected. The level of protection will be identified following the application of a systems ecology approach to define the processes of importance in the chain of dose-response relationships at the levels of the individual, population, community and ecosystem. Interaction matrices will be used to present and collate information collected in previous stages of the project in a systematic way, allowing conclusions to be drawn about the appropriate level for protection.
- A handbook for the initial part of the environmental radiation impact assessment, i.e. reference organisms, scenarios and available models.
- A report on the overall framework for assessment of environmental effects, including reference organisms, doses per unit contamination and dose-effect relationships at the levels of biological hierarchy identified as most appropriate for the application of protection criteria.

### *1.3 Innovation*

The principal innovation FASSET brings to the area is that it sets out to develop a system - that is presently lacking - for linking sources of environmental radioactivity to effects/consequences in the environment. This system is intended for demonstrating to decision-makers and stake-holders what the likely results are in terms of environmental effects/consequences of operations and practices resulting in real or potential radionuclide releases to the environment, whether these have been terminated, are currently operational, or are planned. The conclusions thus reached should be justifiable in terms of the models and parameters that have been selected and how these are inter-linked, and at the same time consider limitations in applicability.

Development of the assessment framework proposed requires the development of new techniques and methodologies in several areas. The first of these is that rather than working along those exposure pathways that eventually lead to doses to humans (as in previous safety assessments of radionuclide releases), an ecosystem approach will be used, in order to identify relevant target organisms and end-points as well as exposure and dosimetric models. This approach will consider the transfer of material within ecosystems, ecosystem processes and over-all limitations in the system productivity. The application of interaction matrices to give a coherent presentation of information from a number of biological and ecological disciplines (e.g. radioecology, population dynamics, systems ecology) is a new development in the field of environmental effects assessment.

In addition, developmental work in the field of dosimetry is included in this project. The development of a dosimetric quantity corresponding to the "equivalent dose" employed in human radiological protection practice will be considered. If sufficient basis exists for the use of such a quantity, it will represent a significant advance in the field of environmental radiation protection.

Other efforts are being made in the area of environmental radiation protection. These include programmes to define permissible environmental concentrations for individual nuclides in various environmental media, derived on the basis of environmental dose standards [US DOE] as well as ecotoxicological approaches where radiotoxicity data together with appropriate safety factors are used to derive certain permissible doses for target biota [AECB]. The development within such programmes is of direct and vital interest to the FASSET project. However, FASSET does not attempt to set standards, which are considered part of national policy, but offers a robust system based on scientific understanding from which standards may be derived, and against which compliance may be judged.

### *1.4 The project's contribution to programme objectives*

The strategic goal of the Research and Training Programme in the Field of Nuclear Energy is to help exploit the full potential of nuclear energy, both fusion and fission, by making current technologies even safer and more economical and by exploring promising new concepts.

The fulfilment of this strategic goal requires that appropriate methods for assessing the safety of different systems are available. The FASSET project aims at providing a formalistic framework for assessment of radiation effects on biota and ecosystems. This framework will be a necessary component for meeting the increasing regulatory demand to broaden the scope of nuclear safety management beyond the protection of humans. As well as providing a framework for environmental radiation protection, the project will develop a set of tools to be used within the framework, including models for evaluating the radiation exposure to biota along with the resulting radiation doses and consequent effects on biota and ecosystems.

The objectives of the generic action in the radiological sciences are to consolidate and advance European knowledge and competence in the radiological sciences that are essential for the safe use of nuclear fission and other uses of ionising radiation, including the management of natural sources of radiation. As the proposed project is concerned with the assessment of the environmental impact of radioactive substances in the environment, the framework developed will be an important tool in safety assessments of nuclear facilities and other sources of ionising radiation. The project is also intended to include radionuclides used in industries other than nuclear power production, including medicinal uses and naturally occurring radioactivity in, for example, mine waste.

The objective of the RT-priority Environmental Transfer of Radioactive Material is to improve the understanding of the behaviour of radioactive material in the environment, with a view to developing sound policy and good practice in managing the impact of natural and artificial sources of radiation on man and the environment. The formulation of the objective of the RT-priority is well harmonised with the increasing focus of regulators in many countries on radiation effects on biota and ecosystems. The proposed project will create a framework for assessment of such radiation impacts. Such frameworks are not yet available.

Part of the proposed project is concerned with providing a substantial improvement in our overall understanding of the behaviour of radioactive material in the environment. The use of this improved overview as a basis for the development of an environmental radiation protection framework will contribute to the development of sound policy and good management. The framework is intended for use by regulators, in assessing potential projects and the setting of regulatory criteria or standards, but also for use by industry or other users wishing to assess the impacts of current or proposed releases. One of the strengths of the framework will be in the presentation of an assessment involving a large number of interrelated factors on a sound scientific basis and in a properly justified manner. This will facilitate understanding of the assessment by both regulators and by technical staff involved with different installations, as well as members of the public.

The results of FASSET will therefore constitute a novel and significant tool for complementing the assessment procedures with the means to include potential impacts on biota and ecosystems. This tool will be based on knowledge developed in several European organisations. Bringing this knowledge together to create a common framework will consolidate and advance in European knowledge and competence in the fields of both radiation and environmental protection.

The EU Basic Safety Standards (Directive 96/29/EURATOM) address environmental impacts only in a very limited sense. It is foreseen that a framework for assessing environmental impacts would facilitate the development of the environmental dimension of the Basic Safety Standards.

# 2 Project work-plan

## *2.1 Introduction*

Assessments of the environmental effects of contaminants, both radioactive and non-radioactive, contain a number of general features. A generalised representation of the assessment process is shown in Figure 2.1. The groups of processes taken into account in an assessment are shown in the left column. Successive stages of the assessment are shown in the middle column and the important information which is produced by each stage and which forms the input to the next stage is shown in the right column. Also, the figure illustrates how the different parts of the assessment link to the workpackages into which the FASSET project has been divided.

The question of environmental protection is very complex as a result of the infinite number of combinations of environmental and biological factors, which may be relevant to different situations. An assessment of environmental effects must therefore include prioritisation at a number of stages so that effort can be concentrated on those parts or functions of the ecosystem (biotic and abiotic) regarded as the most important.

A framework developed as outlined in this project should ensure that for each stage of the assessment process, prioritisation is considered in a structured and systematic way. The scientific basis for the choices made, e.g. approach adopted, significant biological processes and organisms to be studied, etc., can then be documented and made accessible to the widest possible audience, e.g. decision makers and members of the public. In addition, a number of tools are to be developed for use in the assessment process.

The decision-making framework will be generic, i.e. can be adapted to any assessment situation. The tools developed will include reference models to be used in different parts of the assessment and databases relevant to reference sets of critical target organisms identified for different exposure situations. In order to develop the framework and related tools, it will be necessary to carry out a review of available information and methods. It will not be possible within this project to review models and data for all European ecosystems. Therefore, a selection will be made of ecosystems representative of many situations where releases of radionuclides may potentially occur. The identification of representative ecosystems from terrestrial and aquatic environments is important. The selection of ecosystems will become clearer during the course of the project. It can, however, be foreseen to include:

| | |
|---|---|
| Terrestrial | A forest ecosystem |
| | A semi-natural pasture |
| | An agricultural ecosystem |
| | Wetlands, e.g. a peat bog |
| Aquatic | Freshwater |
| | Brackish water |
| | Marine |

The following description of the project plan (section 2.1.1), is structured according to the stage of the assessment process, and describes work pertaining to the prioritisation process in each stage and the development of assessment tools. The individual work-packages are described in general terms in section 2.1.2. A more explicit description of the work to be performed within the work-packages is made in section 2.4 (form B3).

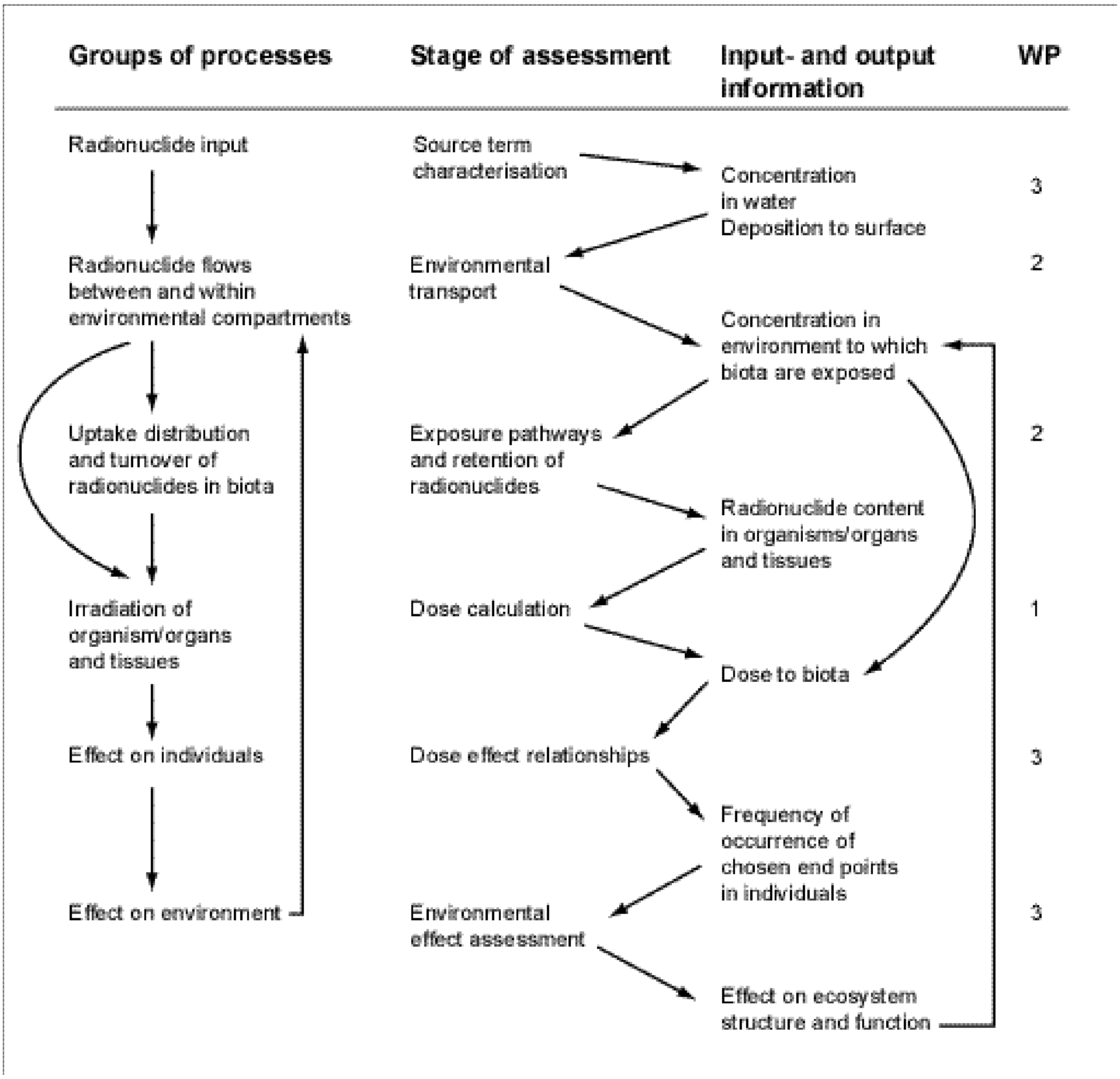


*Figure 2.1 Stages in assessment of the environmental effects of radioactivity. The numbers to the right indicate the workpackage where the assessment stage is treated.*

## 2.1.1 Description of project

The project is taking a practical approach to the assessment and reduction of detrimental environmental effects, based to a large extent on currently available techniques and information. A structured review of the available information will enable the identification of what is critical and relevant to the assessment. Thus the scope of the assessment can be limited to reference objects in a clearly justified way and taking proper account of the uncertainties associated with the assessment process.

### *2.1.1.1 Source term characterisation*

A number of radionuclides will be selected for consideration during the development of an assessment framework. Radionuclide characteristics that will be considered in the selection include coverage of a range of potential sources, half-lives, physical and chemical form, environmental mobility and bioavailability.

Source term characterisation will not be carried out specifically in this project, as this is specific to a particular assessment and a generic approach is not possible. As far as possible, the work of the project and quantities derived as a result of this work will be based on a unit deposition of radionuclides, or a unit concentration in environmental compartments, e.g. water concentration. However, the source term will be considered in the overall framework, insofar as the framework must take into account the range of radionuclide concentrations in the environment and the range of dose rates likely to arise, e.g. from controlled radioactive waste management practices, or persisting in the long-term after an accidental release of radionuclides.

#### *2.1.1.2 Environmental transport*

Ecosystem components that exhibit high accumulations of radionuclides will be identified by simulating the transport and distribution of radionuclides within the selected ecosystems. The simulation will be carried out using existing models. Tools that have been developed in earlier studies will be adapted and developed for use in this project so that they may be applied in order to identify where high levels of accumulation occur, and therefore where enhanced external exposure may occur.

The models used to identify important ecosystem compartments with respect to radionuclide accumulation may be the same models used to consider uptake and retention of radionuclides by biota (see next section). Many models are available, and models have been developed to predict the transfer of selected radionuclides in terrestrial, freshwater, brackish and marine environments. Within the framework of this project, these models will be adapted so that they may be used to identify where uptake to habitat and organism is enhanced. The available models include the widely used equilibrium models using partitioning factors to calculate environmental concentrations. However, dynamic models from the field of systems ecology, simulating material flows through the ecosystem studied will also be applied in this study.

#### *2.1.1.3 Exposure pathways and retention of radionuclides by biota*

The development of the protection framework requires the identification of those compartments of the environment that are likely to accumulate the highest concentrations of radionuclides and the organism behaviour/ uptake potential that will influence the dose rate. This identification will be carried out by assessing the uptake to flora and fauna in order to identify where enhanced internal whole-organism exposure may occur and finally, assessing the distribution of radionuclides within organisms in order to identify organs which may exhibit enhanced activity levels.

The study of exposure pathways will be based on the acquisition and synthesis of information concerning:

- the ecological characteristics of selected European ecosystems e.g., marine, freshwater and terrestrial
- radionuclide uptake by the biological components of these ecosystems. The data compilation will include the collation of information on the uptake of radionuclides to individual organs in plants and animals.

Expert judgement will be applied to the available information and knowledge of the environmental behaviour of radionuclides in the chosen ecosystems. Interaction matrices will be used to define accumulation pathways and functional relationships in the exposure pathways. Simulations will then be carried out to describe activity concentrations in key organisms and organs. The modelling studies will include both equilibrium models and dynamic models based on flows of energy and materials through the ecosystem.

The organisms with enhanced exposure can then be adopted as reference organisms, for which a number of tools can be developed:

- Ecological and transfer information relevant to the reference organisms will be compiled in order to facilitate assessments of the uptake, transfer and retention of radionuclides. Data will be compiled for reference organisms including basic ecological characteristics (life cycle, habitat type etc.) and radionuclides transfer information ($K_d$, concentration factor, transfer factor data etc.). These data will be provided in the form of a database with concomitant explanation for simple application by regulators, authorities and industrial users.
- Simple reference models will be specified for the simulation of radionuclide migration and uptake to the whole-organism (and organs if applicable) for reference species living in representative terrestrial and aquatic European ecosystems. These models will be based on adaptations of the generic models used as a basis for the choice of reference organisms.
- Finally, the uncertainties and limitations associated with the application of simple equilibrium coefficients will be considered.

#### *2.1.1.4 Dose calculation*

Generic sets of fauna and flora are to be identified that are appropriate to the marine, freshwater and terrestrial environments of Europe. The choice of these target organisms is to be based on;

- the level of biological hierarchy (individual cell to ecosystem) at which it is concluded that it would be appropriate to direct protective action;
- the reference organisms identified by the work on transport and uptake of radionuclides by components of the ecosystem (i.e., organisms with the greatest potential for exposure);
- their perceived importance to the healthy functioning of the community or ecosystem, i.e., their ecological significance; and,
- the review of radiation effects (see dose rate-effect relationships, below) that will determine the radiation effects of importance in an environmental context so that specific target tissues and organs, in addition to the whole organism, may be identified.

For these target organisms, corresponding radiation dosimetry models are to be developed. These are intended to permit the estimation of the actual or potential absorbed dose rates to the organisms, from internal and external sources of $\alpha$-, $\beta$- and $\gamma$-radiation, given information on the distributions of natural and contaminant radionuclides in the organism's environment. The final output will be a tabulation of absorbed dose rate coefficients (Gy $s^{-1}$ per unit radionuclide concentration in the relevant environmental compartment) for each target organism for the radionuclides of concern in radioactive waste management.

A review will be made of the approaches that have already been adopted for the estimation of radiation dose to non-human biota (largely, but not exclusively, for the marine environment) to determine if these are appropriate or can form a basis for development. If the approaches are acceptable, then they can be applied to other aquatic ecosystems in a fairly straightforward manner. For the marine environment, information that can be used in the selection of target organisms is already available, e.g. about the effect on the dose rate of factors such as radionuclide accumulation characteristics, differing sizes and habitats. In marine assessments, target organisms previously considered have been fish and large and small crustaceans, in the water column (pelagic) and on the seabed (benthic), and a benthic mollusc. Consideration will be given to whether there is a requirement for additional organisms, e.g. a developing fish egg, phytoplankton cells or a marine mammal for the marine environment or an aquatic insect, an amphibian, water bird or aquatic mammal for freshwater environments.

It can already be foreseen that, in the terrestrial environment, there is a combination of at least two factors that will probably dictate the use of an alternative approach for exposures from external sources. First, there is the difference in density between the organisms and the surrounding atmosphere; and second, it is likely that the radionuclide distribution will be inhomogeneous both on the scale of the radiation interaction length and in relation to the variations in mass density. The effect that these factors have on radiation transport between sources and target will very likely necessitate the use of Monte Carlo methods to derive dose coefficients. Terrestrial organisms might include (but not be restricted to) a large tree, a shrub, a herb, an invertebrate in the soil surface layer (the litter), a burrowing mammal, a herbivore and a predator.

The requirement for additional target organs and tissues in some species will also be considered. It is to be expected that the gametogenic organs will be important targets for inclusion in the dosimetry models.

The output from the dosimetry models will be given in terms of absorbed dose rate. It is recognised, however, that $\alpha$-particles (high LET) are likely to be more effective in causing damage than $\beta$- and $\gamma$-radiation (low LET) for equal absorbed doses. The available information on the relative effects of these radiation types on the endpoints of concern in the natural environment will be reviewed to determine whether a sufficient basis exists to develop a dosimetric quantity corresponding to the “equivalent dose” (absorbed dose x radiation weighting factor) employed in human radiological protection practice.

Consideration will be given to the possibility of validation of the dose rate estimates derived from the models. This has been done earlier using TLD dosimeters attached to fish.

The dosimetry models will then be used to tabulate the absorbed dose rate (Gy $s^{-1}$) per unit radionuclide concentration in the relevant environmental compartment. Estimates of dose rates from the natural background, and from contaminant radionuclides, to the target organisms in specific environments will also be made. These dose rate estimates will provide input information to the development of an overall framework for radiation protection in the environment.

#### *2.1.1.5 Dose-effect relationships*

In this part of the project there will need to be discussion concerning the appropriate level in the biological hierarchy at which protective action should be directed, i.e., where will the radiation damage be induced and what are the consequences at each level in the biological hierarchy extending from the biomolecule to the ecosystem? This will lead to the identification of both the biological attributes of importance and the relevant targets for the development of the dosimetry models. For the attributes of concern, dose rate/response relationships for the chosen endpoints will be tabulated from the information available in the literature.

A review will be made of the many existing assessments of the potential impacts of radiation in the environment and of the wider radiobiological literature, to the extent that it is considered relevant in the context of this project (i.e. taking into account the relevance of the dose rate and duration of exposure). New information from Eastern Europe, e.g. papers reporting the impacts on the environment of the Kyshtym and Chernobyl accidents, will be included in the review as they become available. Feedback from the work on dosimetry will also be included.

If it is determined that the individual organism is the appropriate level to focus protective action (and this is not intended to prejudge the outcome of the initial discussions outlined above), then it is probable that the effects of radiation of interest will include, but not be restricted to, changes in morbidity, mortality, fertility, fecundity, mutation rate. The available information radiation effects on these attributes will be organised into a format that will indicate the approximate dose rate - response relationships and, therefore, the threshold dose rates at which minor radiation effects can currently be expected to become apparent in the defined biological processes in the selected target organisms. An attempt will be made to quantify the intrinsic (i.e., the radiobiological) uncertainty in these threshold dose rates and to indicate possible modifying influences (e.g. extrapolation of laboratory data to natural conditions, other environmental variables).

Because it is known that ionising radiation primarily induces damage in cellular DNA (although it is not unique in this respect), and that this can be quantified as chromosome aberrations, an attempt will be made to correlate such cytogenetic damage with the degree of response in other endpoints of interest. This could then provide an indicator of radiation damage that is relatively easy to measure and monitor.

The information on dose-response relationships will form a basis for definition of the dosimetric target organisms, i.e. target organisms to be considered in dose calculations (see above) and contribute to the development of the overall radiation protection framework for the environment

#### *2.1.1.6 Environmental effect assessment*

In order to assess effects at the environmental level of an increased frequency of occurrence of endpoints observed in individuals, it is necessary to identify the biological effects of irradiation that are likely to be of significance for protection in an environmental context. The extent to which any protective action can be based on a consideration of target organisms will be defined in terms of:

- their ecological sensitivity, i.e., their potential, through feeding habits and habitat occupancy, to be exposed to significant dose rates from radionuclides in their environment that derive from a variety of release scenarios;
- their intrinsic sensitivity to chronic low-level irradiation for the biological endpoints of significance at the relevant level of biological organisation; and,
- their ecological significance, i.e., their importance to the maintenance of the community or ecosystem. The potential requirement for generic representatives of each trophic level in the marine, freshwater and terrestrial environments will need to be considered.

Discussions of the consequences of the primary effects at the biochemical and/or cellular level must, ultimately, take into account population dynamics and the effect on the competitive ability of a population. It is possible that certain primary effects yield no consequences at the level of the population. Conversely, a primary effect that appears to be unimportant could have severe consequences at population or community level. An example is the effect of damage to the Central Nervous System on behaviour; this could influence survival and, hence, result in effects at population level.

Interaction matrices may again be used to analyse the importance of the factors determining the effects at higher levels of organisation of damage to individuals. In this case, the interaction matrices will be based on information about ecosystem processes, e.g. energy and material flows and population dynamics. The matrices may be based partly on quantitative information, but must also use expert judgement. The matrices will help to identify key ecosystem components and processes (including limiting factors), and to determine the effects of various disturbances.

As a result of this work, it will be possible to define the appropriate level in the biological hierarchy (over the range from cell to ecosystem) at which protective action should be directed. Together with the work on other parts of the system it will then be possible to select both the biological endpoints of concern and the appropriate target organisms.

It will also be possible to propose minimum/threshold dose rates at which effects in the environment would be expected to be minimal with a high degree of confidence. A review will also be made of the sources of uncertainty in the proposed dose rates and the effects that this might have on the degree of assurance that the desired level of environmental protection could be achieved.

#### *2.1.1.7 Framework assessment procedure*

The concept of "protection of the environment from radiation" will be examined within the context of approaches that have been adopted for other contaminants and stresses, and the internationally expressed desire to maintain both biodiversity and sustainable development. As an internationally co-ordinated project, consideration must also be given to the relevance of the "Precautionary Principle" that has been incorporated into a number of international conventions.

Within the over-all objective of creating a framework to link source to effect/consequence of ionising radiation in the environment, a review will be made of existing frameworks for environmental assessment used in different environmental management or protection programmes. This review will extend outside the field of radiation protection, where such schemes are presently scarce, and consider, *inter alia*, frameworks for managing risks from genotoxic chemicals. Based on this review, a 'generic' framework will thus be created. This generic framework will then be adapted by taking into account the work in other parts of the project, which will identify the relevant elements of a framework related to ionising radiation in the environment. Thus, a framework which specifically addresses the assessment of potential environmental impacts of ionising radiation will be the final product of the project.

#### *2.1.1.8 Uncertainties*

An important feature of all parts of the project is the characterisation of the sources and magnitudes of all of the uncertainties associated with different parts of the suggested assessment framework. These uncertainties will be documented in a clear and systematic way so that they can easily be taken into account in assessments carried out with the proposed framework.

### 2.1.2 Achievement of proposal objectives

The division of the project into work packages does not follow the division into stages of an environmental effect assessment as outlined above and in Figure 2.1. The division into work packages follows to a large extent the approaches that will be adopted to accomplish the objectives at each assessment stage. Some questions which must be addressed in the assessment framework cannot be addressed quantitatively, but should be addressed in a systematic manner in order to demonstrate compliance with regulatory demands. Thus work package 3 incorporates work tasks which must be approached in a qualitative, or semi-quantitative manner. Work package 2 is a review of existing work in two stages of the assessment process for which a number of models and a large amount of data already exist. Work package 1 represents the development of new quantitative techniques in the area of dosimetry. Work package 4 represents the development of an overall framework, taking into account the work carried out in the other work packages and setting the results of this work in a wider context.

A flow diagram of the objectives of the different work packages and the intended information flows between the work-packages are shown in Figure 2.2. The contributions of the individual work packages to the development of an overall framework are also shown.

***WP1***

WP1 is concerned with the area of environmental dosimetry. The main objective of the work package is to develop radiation dosimetry models for defined sets of generic fauna and flora. The development of dosimetry models will be carried out after a review of current advances in environmental dosimetry, with attention being paid especially to the following questions

- the modelling of external exposure in terrestrial environments, considering the difference in density between the target organisms and the surrounding atmosphere, and the inhomogeneous distribution of radionuclides both on the scale of the radiation interaction length and in relation to the variations in mass density
- of the geometry of the exposed organisms with respect to both size and habitat, including the distribution of radionuclides between different organs
- the use of weighting factors to take into account the different biological effectiveness of $\alpha$-particles as compared with $\beta$- and $\gamma$-radiation.

Following definition of the target organisms (together with WP2 and WP3), the dosimetry models developed will be adapted and used to calculate the absorbed dose rate. Dose rate coefficients will be tabulated for the selected radionuclides (Gy $s^{-1}$ per unit radionuclide concentration in the relevant environmental compartment) for a range of source term scenarios and for each target organism. These data will then be combined with the output of WP2 to provide a comprehensive database for estimating the dose rates in contaminated European environments. Estimates of dose rates from the natural background and from contaminant radionuclides to the target organisms in specific environments will also provide a context for the work of WP3.

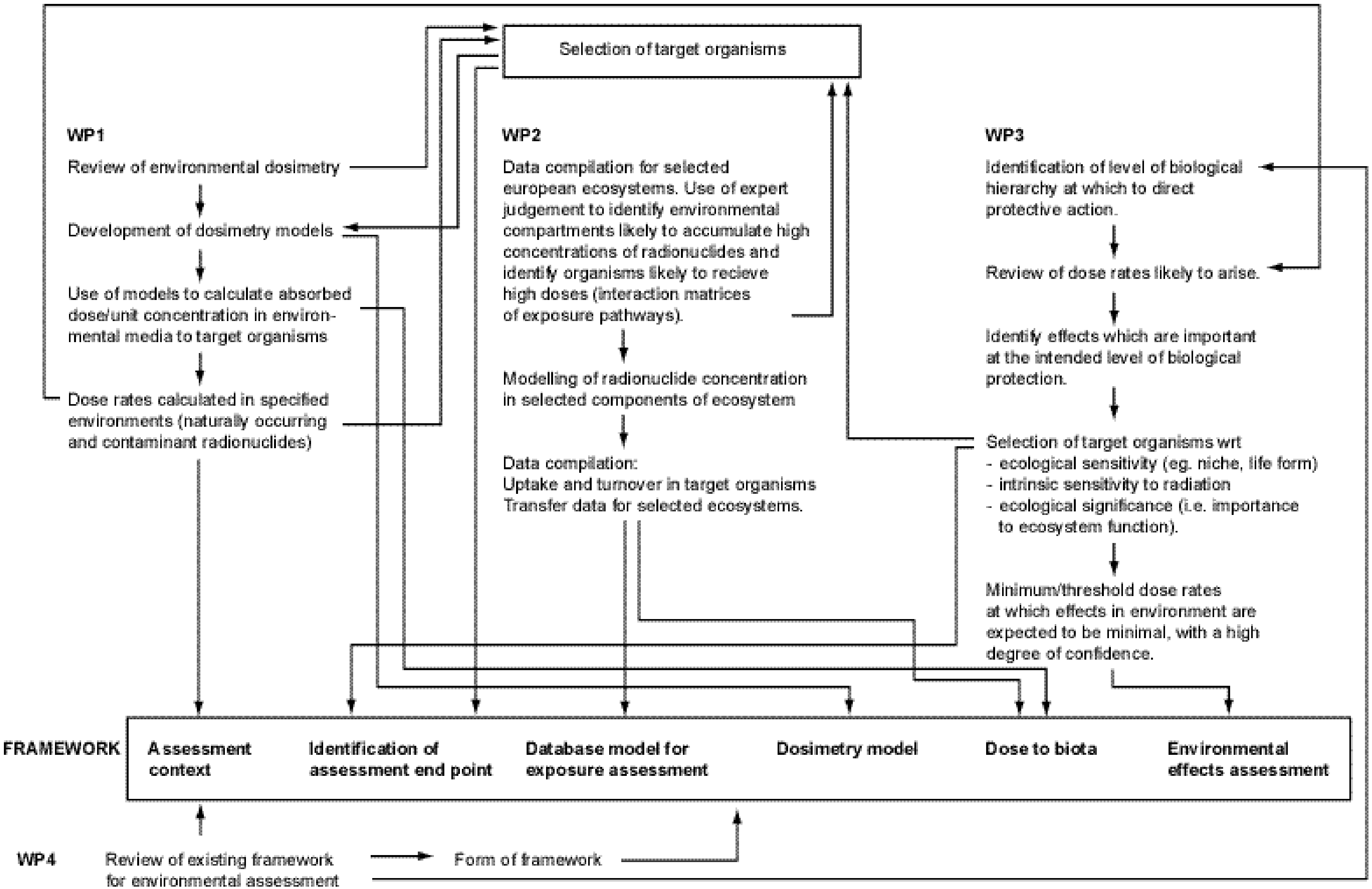


*Figure 2.2 Information flows between work packages and contributions to the environmental radiation protection framework.*

***WP2***
The activities of WP2 are concerned with exposure modelling. The aim of the first part of the work is to identify environmental compartments where radionuclides can be expected to accumulate to high concentrations, to identify organisms where enhanced exposure is likely to occur (both external exposure and internal whole organism exposure) and finally, to identify organs which may exhibit enhanced activity levels. This work will be based on a comprehensive review of available information on:

- the ecological characteristics of selected European ecosystems
- the environmental fate and transfer of selected radionuclides
- uptake and turnover of radionuclides in biota
- the distribution of radionuclides within organisms.

A synthesis of the available information will be made in the form of modelling studies (using available models) and expert judgement, documented in the form of interaction matrices.

The synthesis of information about exposure pathways will be used as a basis for the identification of target organisms to be included in the assessment framework (together with WP1 and WP3).

On identification of the target organisms, the transfer and uptake of radionuclides to the target organisms will be assessed, using the information gathered earlier in the project. This will result in the compilation of relevant ecological and transfer information as a database-model, simulating radionuclide migration and uptake to the whole-organism (and organs if applicable) for target organisms living in representative terrestrial and aquatic European ecosystems. This model will be combined with the output of WP1 to provide a comprehensive database for estimating the dose rates in contaminated European environments. The database will include data for those variables identified as being of importance with respect to the transport, uptake and turnover of radionuclides in the selected target organisms, and will be accompanied by an explanatory manual. Simple models, executable via the database model, will also be specified.

***WP3***
WP3 is concerned with interpretation of information about doses to individual organisms and concentrations of radionuclides in the environment in terms of radiation effects in the environment. This WP will address the important question of which biological effects of irradiation are likely to be of significance for protection at the appropriate level of biological organisation and in an assessment context. In order to do so, review and discussions will be made of the following topics

- which is the appropriate level of biological organisation for protective action
- what are the appropriate biological endpoints of concern
- what are the consequences of radiation effects on individuals at higher levels of biological organisation, i.e. at population, community and ecosystem levels
- which target organisms can be used in a radiation protection framework.

Based on the results of this discussion, target organisms will be identified from the point of view of their importance in terms of ecosystem structure and function and the likely severity of radiation induced changes in these species.

The input to the discussions will consist of existing assessments of the impact of radiation in the environment, the wider radiobiological and ecological literature and input from WPs 1 and 2. The work of this WP is of a qualitative (or semi-quantitative) nature. In order to structure the discussion, and to document the conclusions and the choice of target organism, the use of interaction matrices will be considered.

The final product of the WP will be to identify a range of dose rates at which different degrees of effects in the environment would be expected (including the threshold dose rates at which effects would be expected to be minimal) with a high degree of confidence. These dose rates will form an important input to the overall framework.

***WP4***

The work of WP4 is concerned with the structure of the environmental assessment framework and the coordination of the results of the other WPs into a cohesive environmental assessment system. The framework structure will be determined following reviews of frameworks used in related fields, systems under development in other countries for environmental radiation protection and the requirements for environmental protection imposed by international agreements and other legislation.

### 2.1.3 Information exchange

The project is dependent on the flow of information between the different work packages, and many aspects of the work are of an iterative nature, following inputs from the various work items. To ensure the success of the project, meetings of participants of the various work packages have been scheduled simultaneously so that they can take place at the same location. The meetings will thus take the form of workshops, where the individual work packages meet for two to three days, and the exchange of information between groups takes place in special joint sessions or plenary sessions organised during the remainder of the workshop. It is possible that smaller work-package meetings will be needed between workshops.

In all, six workshops are planned. The main objectives of these workshops with respect to the progress of the individual workpackages are summarised in the table below.

| Workshop at month no. | WP 1 | WP 2 | WP 3 | WP4 |
|---|---|---|---|---|
| 0 | Start-up meeting – detailed planning of the work in the workpackages | | | |
| 6 | Review available dosimetric models | Review progress of database on eco-systems | Definition of level of biological hierarchy at which to direct protective action | Review of infor-mation on existing frameworks for assessment of environmental impacts |
| 18 | Review progress of target organism selection | Review of eco-system models and definition of generic biota | Summary of avai-lable data on radia-tion effects and dose/response relationships | Review of generic scheme |
| 24 | Review of final set of target organisms | | | Review of final version of generic framework |
| 30 | Presentation of dosimetric models and final WP-report | | Presentation of the final results | |
| 36 | | Presentation of final database on reference organisms and their habitat | | Presentation of final report |

## 2.2 Project planning and timetable

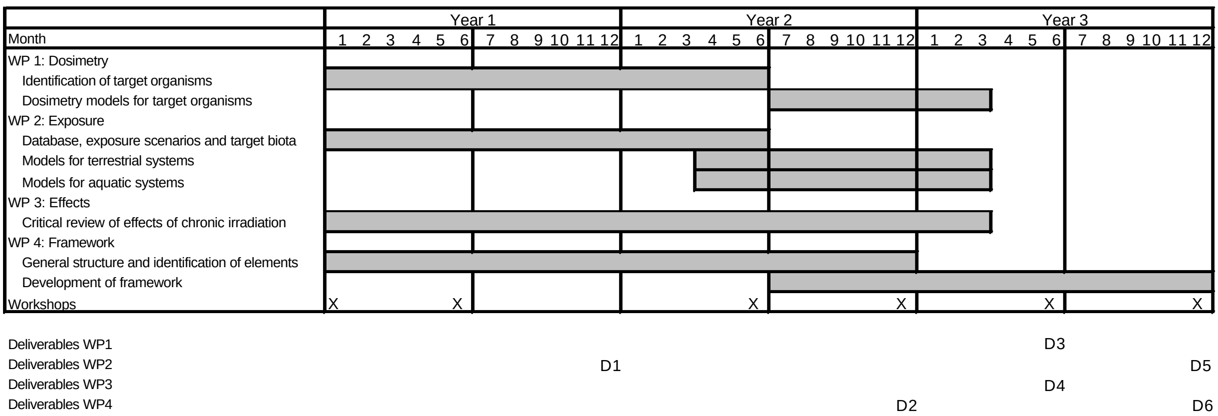


*Figure 2.3 Schedule for the FASSET project*

## 2.3 Graphical presentation of project's components

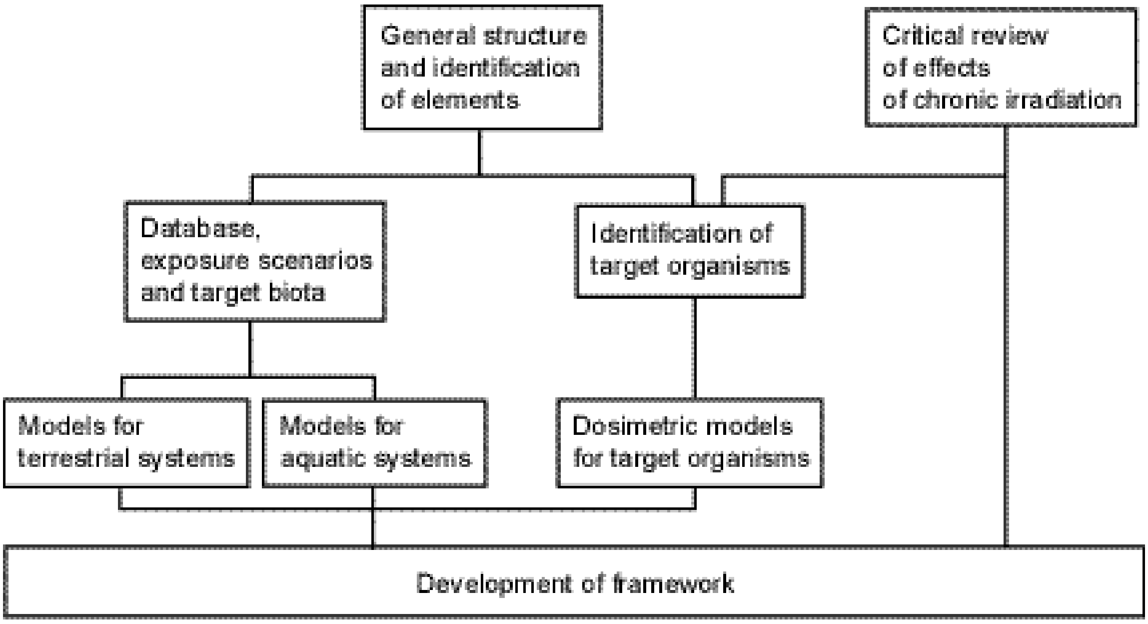


*Figure 2.4 Pert scheme illustrating the interconnections between the components of the FASSET project*

## 2.4 Detailed project description

Work-package list

| Work-package No | Work-package title | Lead contractor No | Person-months | Start month | End month | Phase | Deliv-erable No |
|---|---|---|---|---|---|---|---|
| WP1 | Dosimetry models for generic/reference organisms | 10 | 65 | 1 | 27 | | D3 |
| WP2 | Exposure pathways | 13 | 82 | 1 | 27 | | D1, D5 |
| WP3 | Effects of low dose rate chronic irradiation of native wild organisms | 5 | 46 | 1 | 27 | | D4 |
| WP4 | Framework for assessing the radiological impact on the environment | 1 | 72 | 1 | 36 | | D2, D6 |
| | TOTAL | | 265 | | | | |

NOTE: In addition to the manpower listed in the above table, an effort of 10 manmonths will be input for the scientific and administrative coordination of the project.

Deliverables list

| **Deliverable No** | **Deliverable title** | **Delivery date** | **Nature** | **Dissemination level** |
|---|---|---|---|---|
| D1 | Report on identification of target organisms, release scenarios and exposure matrices. | 12 | Re | PU |
| D2 | Report on existing programmes for environmental assessment and management of environmental risks from ionising radiation and hazardous chemicals. | 24 | Re | PU |
| D3 | Report on dosimetry, selection of target organisms, dosimetry models, doses per unit contamination and doses from natural background. | 30 | Re | PU |
| D4 | Report providing a justified level of biological hierarchy to be protected, a discussion on radiation effects including dose/response relationships, a discussion of uncertainties and proposed threshold dose rates. | 30 | Re | PU |
| D5 | Handbook for the initial part of environmental radiation impact assessment – reference organisms, scenarios and available models. | 36 | Re | PU |
| D6 | Final report: System for linking source to environmental effect/consequence including reference sets for exposure, dosimetry and biological effects. | 36 | Re | PU |

Detailed project description broken down into work packages

| **Work package number:** | **WP 1** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Start date or event:** | 1 | | | | | | |
| **Partner number:** | 1 | 7 | 8 | 10 | 11 | 13 | 14 |
| **Person-months per partner:** | 4 | 2 | 8 | 30 | 8 | 12 | 1 |

**Objectives and input to workpackage**

The objectives of this work package are:

- to define sets of generic fauna and flora that are appropriate to the marine, freshwater and terrestrial environments of Europe. The identification of relevant target organisms will depend on the output of both WP 2 and WP 3 as well as on a review of environmental dosimetry, which will highlight the factors influencing dose.
- to develop the radiation dosimetry models for the estimation of the actual or potential absorbed dose rates to the target organisms, from internal and external sources of α-, β- and γ-radiation, given information on the distributions of natural and contaminant radionuclides in the organism's environment.

The final output will be a tabulation of absorbed dose rate coefficients (Gy $s^{-1}$ per unit radionuclide concentration in the relevant environmental compartment) for each target organism for the radionuclides selected in this project.

**Description of the work**

The first step will be to examine the approaches that have already been adopted for the estimation of radiation dose to non-human biota (largely, but not exclusively, for the marine environment) to determine if these are appropriate or can form a basis for development. If the approaches are acceptable, then they can be applied to freshwater systems, perhaps with some additional or alternative organisms, in a fairly straightforward manner. However, in the terrestrial environment, there is a combination of at least two factors that will probably dictate the use of an alternative approach for exposures from external sources. First, there is the difference in density between the organisms and the surrounding atmosphere; and second, it is likely that the radionuclide distribution will be inhomogeneous both on the scale of the radiation interaction length and in relation to the variations in mass density. The effect that these factors have on radiation transport between sources and target will very likely necessitate the use of Monte Carlo methods to derive dose coefficients.

Depending on the input from WP2 and WP3, it is envisaged that the target organisms might include (but not be restricted to) :

*Marine:* fish, large and small crustaceans, in the water column (pelagic) and on the seabed (benthic), a benthic mollusc, a developing fish egg, phytoplankton cells and a marine mammal;
*Freshwater:* fish, large and small crustaceans, in the water column (pelagic) and on the river or lake bed (benthic), a benthic mollusc, an aquatic insect, an amphibian, a water bird and an aquatic mammal;
*Terrestrial:* a large tree, a shrub, a herb, an invertebrate in the soil surface layer (the litter), a burrowing mammal, a herbivore and a predator.

When a suitably comprehensive range of target organisms (and organs) and habitats has been identified, the point source dose distribution approach and the Monte Carlo methodology will be adapted, as appropriate, to calculate the dose rate coefficients per unit radionuclide activity in the relevant environmental compartments. This will require the definition of the target organisms in terms of their geometry, their behaviour (this can modify their exposure to different external sources of radiation) and their capacity to accumulate the radionuclides of concern,

The output from the dosimetry models will be given in terms of absorbed dose rate. It is recognised, however, that α-particles (high LET) are likely to be more effective in causing damage than β- and γ-radiations (low LET) for equal absorbed doses. The available information on the relative effects of these radiations on the endpoints of concern in the natural environment will be reviewed to determine whether a sufficient basis exists to develop a dosimetric quantity corresponding to the "equivalent dose" (absorbed dose x radiation weighting factor) employed in human radiological protection practice.

In one instance, for a contaminated marine environment, it has proved possible to provide some validation of the dose rate estimates derived from the models using TLD dosimeters attached to fish. If appropriate and feasible, a similar validation exercise will be conducted in the terrestrial environment.

**Deliverables**

**D3:** A report providing a detailed discussion of radiation dosimetry as it is applied to wild organisms in their natural habitat; justification for the selection of the target organisms (and internal organs and tissues) to be used in the development of dosimetry models, a description of the dosimetry models (including the assumptions made, and a tabulation of the input data required) and a summary discussion of the uncertainties in the results and an assessment of their practical validity. The report will also contain a tabulation of the output from the models in terms of the absorbed dose rate (Gy $s^{-1}$) per unit radionuclide concentration in the relevant environmental compartment and estimates of dose rates from the natural background, and from contaminant radionuclides, to the target organisms in specific environments.

**Milestones and the expected result**

1. A review of the available information on environmental dosimetry and preliminary selection of target organisms and organs to allow model development to commence (at 6 months).
2. Revision and finalisation of the selection of target organisms and organs, with input from WP2 and WP3 (24 months).
3. Finalisation of the dosimetry models and presentation of the results (30 months).
4. Final report (at 30 months)

| Work-package number : | WP 2 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start date or starting event: | 1 | | | | | | | | | | | | |
| Partner number: | 1 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Person months per partner: | 4 | 1 | 16 | 6 | 3 | 6 | 4 | 6 | 9 | 8 | 14 | 1 | 4 |

**Objectives**

The two main objectives of this work-package are :
(a) to identify the components of representative European terrestrial and aquatic ecosystems for which external and internal exposure from radiation may be high and to present this information to WP1 for consideration in selection of target organisms.
(b) to assess the transfer and uptake and turnover of radionuclides to the target organisms identified in (a) above. The result of this work will be the compilation of relevant ecological and transfer information and the adaptation of generic models, simulating radionuclide migration and uptake to the whole-organism (and organs if applicable) for generic species living in representative terrestrial and aquatic European ecosystems.

**Description of work**

The development of the protection framework requires the identification of those compartments of the environment that are likely to accumulate the highest concentrations of radionuclides and the organism behaviour/ uptake potential that will influence the dose rate. This needs the application of expert judgement to the available information and knowledge of the environmental behaviour of radionuclides in selected ecosystems. The following tasks will be involved in objective (a):
(i) Data compilation – acquisition and compilation of relevant data sets combining information on the ecological characteristics of European ecosystems and concentration factors/distribution coefficients for common biotic and non-biotic components of these ecosystems. This will include the collation of information on the uptake of radionuclides to individual organs in plants and animals which may provide important input data for the dosimetric models to be developed under WP1.
(ii) The use of expert judgement and existing data to identify the factors which are important in determining the exposure of organism and organs in the different environmental compartments (documented as interaction matrices). Simulations will then be carried out to describe activity concentrations in key ecosystem components.
The ecosystems to be considered may include a semi-natural pasture, a forest ecosystem, freshwater, coastal-brackish and marine ecosystems.

A synthesis of the currently available information (databases, expert knowledge and simulations) on the selected ecosystems together with input from the other work-packages, will allow appropriate reference organisms to be identified. The choice of reference organisms will be fully justifiable.

The development of models and databases (objective (b)) for the reference organisms will be based on the work carried out under objective (a). Data will be compiled for reference organisms and provided in the form of a data base with concomitant explanation for simple application by regulators, authorities and industrial users. As an extension to this database, simple models will be developed which are executable through a user-friendly interface. The models and database developed will include the processes identified as being most important in terms of the potential consequential exposure of the reference organisms. Finally, the uncertainties and limitations associated with the application of simple equilibrium coefficients will be considered.

The result of this work will be a well-documented set of guidelines and tools which can be applied in the cases of routine, projected or accidental releases of radioactivity, in order to assess the transfer of radionuclides to organisms and their habitat. Combined with developments in WP1 exposure (in terms of dose) may be calculated.

**Deliverables**

**D1:** A report defining the approaches taken in selecting reference biota from an exposure pathways perspective
**D5:** A handbook providing guidelines and recommendations on performing the initial part of an environmental radiation impact assessment, i.e. reference organisms, basic ecological information, environmental transfer coefficients, and available models for predicting concentrations in flora and fauna and their environment etc.

**Milestones and expected results**

The milestones to be attained, in order of occurrence, over the project duration include -

-Development of a database including (i) common European ecosystem characteristics, (ii) concentration factors for biota under the range of ecological conditions found in Europe and (iii) distribution coefficients for water and sediments under the range of biogeochemical/sedimentological conditions found in Europe (12 months).

-Completion of review/simulation work on selected terrestrial and aquatic ecosystems and identification of components of selected European ecosystems where radionuclides accumulate or where exposure may be high. Definition of the generic biota set to be adopted in the assessment framework (with WP1 and WP3) (18 months).

-Synthesis of information for reference organisms and their habitat including compilation of data for important variables and model-database development (36 months).

| **Work package number:** | **WP 3** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Start date or event:** | 1 | | | | | | | | | |
| **Partner number:** | 1 | 3 | 4 | 5 | 7 | 8 | 11 | 13 | 14 | 15 |
| **Person-months per partner:** | 3 | 1 | 6 | 4 | 3 | 8 | 6 | 12 | 2 | 1 |

**Objectives and input to workpackage**

The primary task will be to develop criteria for the protection of the environment from radiation that would both demonstrate that the problem is being adequately and consistently addressed, and be generally acceptable to policy makers and the wider lay public, as well as within the scientific community. This will require a critical examination of the level at which protective action should be directed (the population, ecosystem, biodiversity etc.) taking due account of the available knowledge concerning the biological effects of radiation. A sound justification will be given for the choices made.

The input to this WP will consist of existing reviews and assessments of the impacts of radiation in the environment; the wider radiobiological and ecological literature; and, feedback from WP 1. The output from this WP will help define the dosimetric target organisms for WP 1. This WP will also contribute to the development of a radiation protection framework for the environment within WP 4, especially in the determination of dose-rate thresholds or minimum dose rates at which effects in the environment are expected to be minimal with a high degree of certainty.

**Description of the work**

In order to provide input to the definition of target organisms for the environmental protection framework it will be necessary to carry out reviews and discussions on the following topics:
the hierarchy of biological organisation - over the range from cell to ecosystem - at which it is appropriate to direct protective action;
the range of dose rates likely to arise from controlled radioactive waste management practices, and to persist in the long-term after an accidental release of radionuclides when remediation activities might be required;
the biological effects of irradiation that are likely to be of significance for protection, at the intended biological level, in an environmental context; and,
the extent to which any protective action can be based on a consideration of target organisms defined in terms of:

- their ecological sensitivity, i.e., their potential, through feeding habits and habitat occupancy, to be exposed to significant dose rates from radionuclides in their environment that derive from a variety of release scenarios;
- their intrinsic sensitivity to chronic low-level irradiation for the biological endpoints of significance at the relevant level of biological organisation; and,
- their ecological significance, i.e., their importance to the maintenance of the community or ecosystem. The potential requirement for generic representatives of each trophic level in the marine, freshwater and terrestrial environments will need to be considered.

The scientific basis of the choice of approach, the significant biological processes and the target organisms will be fully documented and made accessible to the widest possible audience. The use of interaction matrices may be considered in this respect.
The input to these discussions will consist of the many existing reviews and assessments of the potential impacts of radiation in the environment, including new information becoming available from the FSU; the wider radiobiological literature to the extent that it is concluded to be relevant in the context of this project (e.g., acute and high dose rate exposures versus chronic, low-level exposures extending over a significant fraction of the life time of the organism) and feedback from WP 1. It is probable that the effects of radiation of interest will include, but not be restricted to, changes in morbidity, mortality, fertility, fecundity and mutation rate. The available information will be organised into a format that will indicate the approximate dose rate - response relationships and, therefore, the threshold dose rates at which minor radiation effects can currently be expected to become apparent in the defined biological processes in the selected target organisms. An attempt will be made to quantify the intrinsic (i.e., the radiobiological) uncertainty in these threshold dose rates, e.g. associated with extrapolation of data obtained from laboratory studies with a typical laboratory organisms to the natural environment, or arising from other environmental variables, both natural and anthropogenic.
Because it is known that ionising radiation primarily induces damage in DNA, which can be quantified as chromosome aberrations, an attempt will be made to correlate such cytogenetic damage with the degree of response in other endpoints of interest. This could then provide an indicator of radiation damage that is relatively easy to measure and monitor.

**Deliverables**

1. **D4:** A report which proposes the level in the biological hierarchy at which protection action should be directed and selects both the biological endpoints of concern and appropriate target organisms for inclusion in the framework. The report will also discuss the effects of radiation on the defined endpoints of concern in the selected target organisms. A summary of the developed dose rate/response relationships will be given together with a discussion of the sources and magnitudes of the associated uncertainties, and finally, the minimum/threshold dose rates at which effects in the environment would be expected to be minimal with a high degree of confidence will be proposed.

**Milestones and the expected result**

1. Definition of the appropriate level in the biological hierarchy at which to direct protective action and develop the consequences of this in terms of its practical application in a system of environmental protection. (6 months).
2. A summary of the available data on radiation effects and dose rate/response relationships. Choice of target organisms and target organs from the protection perspective for transmission to WP 1. Proposal of preliminary minimum/threshold values of dose rate to provide for environmental protection as input to WP 4. (18 months).
3. Final report (30 months).

| **Work-package number :** | WP 4 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start date or starting event:** | 1 | | | | | | | | | | | | | |
| **Partner number:** | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Person-months per partner:** | 4 | 12 | 4 | 2 | 3 | 4 | 8 | 10 | 4 | 5 | 7 | 6 | 2 | 1 |

**Objectives**

Within the over-all objective of creating a framework to link sources to effects/consequences of ionising radiation in the environment, WP 4 will review existing frameworks for environmental assessment used in different environmental management or protection programmes. This review will extend outside the field of radiation protection, where such schemes are presently scarce, and consider, *inter alia*, frameworks for managing risks from genotoxic chemicals. A 'generic' framework will thus be created. This generic framework will be used as input to WPs 1-3. The relevant elements of a framework related to ionising radiation in the environment, identified in WPs 1-3 in discussions with WP 4, will be incorporated into the framework. Thus, a framework, which specifically addresses the environmental impact of ionising radiation, may be created, which will be the final product of the project.

**Description of work**

The first step in the 'generic' phase of WP 4 will be to identify existing frameworks that are relevant to the current project. In general, programmes addressing the management of environmental risks can be grouped (although somewhat arbitrarily) into three categories:

- management through pathway-based analysis of exposure, often involving environmental standards (e.g. radiation dose to certain organisms, or concentrations of radionuclides in environmental media),
- management through process standards relevant to (a) specific source(s), based on *best available technology* (BAT) and similar criteria of technical status and performance, and
- pure management standards, which may include certification schemes or schemes that ensure that positive actions are taken to protect the environment and where continuous performance improvement is sought, such as the EC Eco-Management and Audit Scheme (EMAS).

Mainly pathway-based schemes are relevant to the current project, but aspects of other schemes may be considered and incorporated, when appropriate.

The project will review the general background to the ambitions and aims that are expressed the Rio Declaration and related UNCED documents, and will also review the approaches and assessment schemes being adopted by a number of international and governmental agencies and industry, e.g. the detailed assessment/management procedures currently being developed by the US Department of Energy and the Atomic Energy Control Board of Canada. Furthermore, frameworks outside the area of radiation protection will be considered, with particular emphasis on programmes related to management of risk from genotoxic substances. Examples of such programmes are the EC programmes on assessment and reduction of risks associated with existing and new chemicals.

This information will be used to set up a general back-bone for a scheme for assessment of environmental impact that incorporates:

- a review of how the ambitions and aims in currently used pathway-based schemes for assessing and managing environmental risks correspond to the general goal of achieving sustainable development, and
- a review of those elements of the schemes that can be identified as necessary for linking source – exposure – dose – effect/consequence, for hazardous (either radiologically or chemically) substances.

Through continuous exchange with WPs 1-3, specific components that are needed for assessing radiation impact in the environment (e.g. quantities and units, dose models, endpoints, etc) identified and defined in WPs 1-3 will be incorporated into the scheme. In this way, a first 'system' linking sources to effects/consequences in the environment will be created. This system will be made available for use by, e.g., authorities assessing environmental impact in specific situations, and implementers, seeking to demonstrate compliance with environmental goals.

**Deliverables**

**D2**: Report reviewing the aims and ambitions of existing programmes for environmental assessment and management of environmental risks associated with ionising radiation and hazardous, in particular genotoxic, chemicals.

**D6**: Report describing a system for linking source to environmental effect/consequence (outside public health effects), including reference sets for e.g. exposure, dosimetry and biological effects

**Milestones and expected results**

1. Preliminary compilation of information on national and international environmental programmes relevant to a framework for assessing environmental impact of ionising radiation (6 months).
2. Finalisation of the generic scheme, taking into consideration input from WPs 1-3 (18 months).
3. Final version of generic framework (D2) as well as first preliminary drafts of elements for the final report (24 months)
4. Final report (D6; 36 months)

# 3 Scientific and Technical Prospects

All the member states participating in the project have major nuclear programmes. In these countries both the waste management issue and the safe management of discharges from power plants are of great importance. It is of utmost importance for the continued safe and economic utilisation of nuclear power that appropriate protection of the environment from radiation induced effects can be demonstrated. There is an increasing requirement for demonstration of environmental protection within the EIA process. Failure to demonstrate compliance with requirements for environmental protection can result in enormous costs in the failure of proposed projects, which are otherwise viable. There are four categories of customer for the output of this project:

- The Commission and national authorities will have the tools to develop a transparent system of standards and criteria to provide for environmental protection from radiation.
- The nuclear industry will be able to use the framework and the supporting tools to determine the likely radiation impacts of its activities on the natural environment.
- The scientific community.
- The lay public.

Three of these four categories are represented in the consortium of partners proposing to carry out this project.

In practice, the same framework will be applicable to radioactive materials (artificial or natural) released to the environment from non-nuclear industry sources, e.g., hospital nuclear medicine departments, the phosphate ore processing industry, etc. It would also be applicable to the remediation activities following either the decommissioning of a nuclear site or a major accidental release from a nuclear facility.

The main target groups for dissemination of the results of the project are national regulatory authorities and sections of the nuclear power industry dealing with routine and accidental releases or with waste disposal. However, the project may be of interest to regulators and industry in the non-nuclear area, particularly where radiation sources or radioactive substances are used (e.g. in industrial processes or medicine) or where naturally occurring radioactive substances lead to high levels of environmental radioactivity. The framework developed may also be of interest in the area of the assessment of hazardous substances, particularly with respect to genotoxic chemicals. The assessment of environmental effects of hazardous substances is also a developing area. Assessment frameworks exist, but none is similar to the one proposed in this project.

The project will adopt an open dissemination strategy. The progress of the work will be displayed in relevant public symposia, some of which will be organised following initiatives from the project. IAEA has offered to assist with arrangements of symposia on the protection of the environment from the effects of ionising radiation.

The tools developed during the project will be made widely available. The NRPA plans to establish a “user forum” for users of the models and databases developed, fulfilling both an educational role and a forum for the exchange of ideas between different users.

Another forum for dissemination of the results will be end-user seminars and possibly cluster meetings arranged by the commission.

A web site will be set up and made publicly available when the information developed through the project is mature enough to be widely displayed.

The consortium has close contact with the International Union of Radioecologists. The members of the IUR in Eastern European countries will be useful in facilitating the dissemination of the project's results in those countries.

There are close connections between the project and ICRP, e.g. through David Cancio (CIEMAT and member of ICRP Committee 4) and through ICRP's scientific secretary, Jack Valentin. The ICRP has committed itself to develop its approach to environmental protection, although the form and general terms of reference for these activities have not been established. However, several consortium members are involved in these actions.

A TIP and a consortium agreement are not relevant to this project as it is the intention that the results of the project will be made generally available, in published form and via the Internet, and disseminated as described above.

# 4 Project Management

## *4.1 Project organisation*

The FASSET project will be organised according to the organisation chart in Figure 4.1.

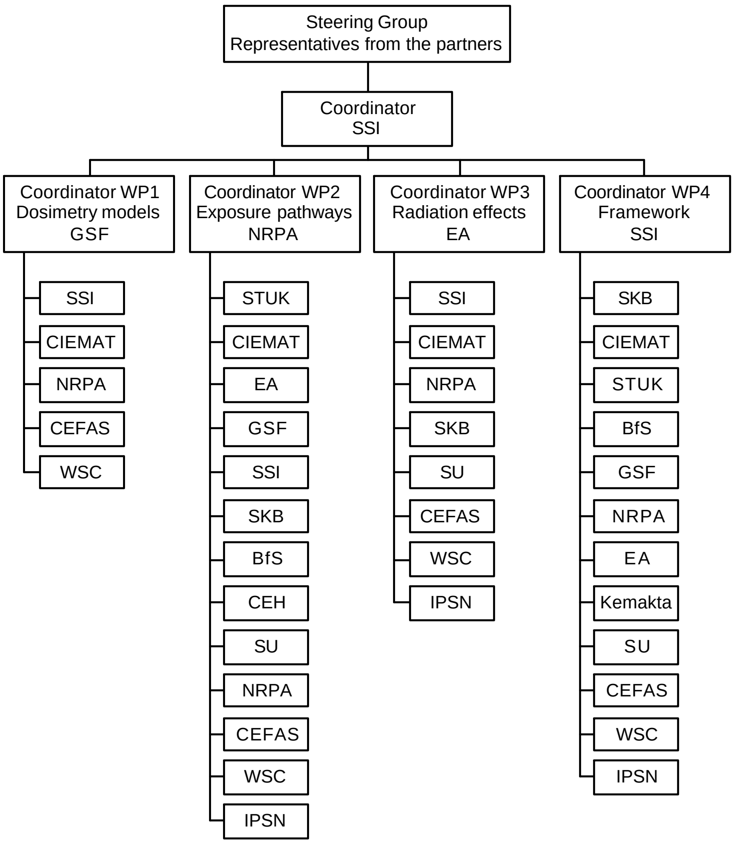


*Figure 4.1 Organisation chart for the FASSET project.*

Decisions on the management and economy of the project will be taken following discussions within the Steering group, consisting of members from all partners and chaired by the coordinator. The coordinator will be responsible for the management of the project. The coordinator will also be responsible for contacts with EC on administrative as well as scientific matters.

The four workpackages will be coordinated by the organisations shown in the figure. The workpackage coordinators will be responsible for the distribution of tasks to the different partners contributing to the workpackage. The workpackage coordinators report directly to the coordinator of the project.

| Partner no | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Total/WP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coordination | 10 | | | | | | | | | | | | | | | 10 |
| WP1 | 4 | | | | | | 2 | 8 | | 30 | 8 | | 12 | 1 | | 65 |
| WP2 | 4 | | 1 | 16 | | 6 | 3 | 6 | 4 | 6 | 9 | 8 | 14 | 1 | 4 | 82 |
| WP3 | 3 | | 1 | 6 | 4 | | 3 | 8 | | | 6 | | 12 | 2 | 1 | 46 |
| WP4 | 4 | 12 | 4 | 2 | 3 | | 4 | 8 | 10 | 4 | 5 | 7 | 6 | 2 | 1 | 72 |
| Total/partner | 25 | 12 | 6 | 24 | 7 | 6 | 12 | 30 | 14 | 40 | 28 | 15 | 44 | 6 | 6 | 275 |

*Figure 4.2 Manpower input from the partners to the different workpackages.*

## 4.2 Obligations and Schedule for meetings and reporting

Progress meetings/workshops are planned to be held at times indicated in the schedule on page 19. At these workshops the progress of the work in the workpackages will be reviewed and plans for the continued work will be laid down. The organisation of the workshops will include both group sessions within the workpackages and plenary sessions. The workshops will be documented in minutes produced by the workpackage coordinators as well as the project coordinator.

The steering group will meet in conjunction with the progress meetings/workshops. The coordinator will be responsible for producing minutes from the steering group meetings.

The progress of the project will be exposed in workshops, symposia and in meetings within suitable clusters set up by the EC. The main objective of these meetings will be to report and disseminate to a wider audience the progress and achievements of the project within the context of the EC Nuclear Energy Programme. The project will be strictly obliged to participate in not more than two such meetings during the course of the project. The level of participation in these meetings will be decided on a case by case basis in agreement between the coordinator and the EC officials.

The project will keep up to date with other international conferences and symposia that could be relevant for presentation of the progress of the project or where essential input to the project could be expected to be found. If the participation of the project exceeds one person, or if the conference/symposium is located outside the EU member states, prior approval of the EC is required, in order to make the costs for participation eligible.

Figure 4.3 shows a schedule for the reporting from the project to EC.

<table>
<tr><th colspan="2">Reports/Cost Statements</th><th>Submission time<br>(time after contract start – months)</th></tr>
<tr><th colspan="3">Reports</th></tr>
<tr><td colspan="2">Minutes of progress meetings</td><td>Within 1 month of each meeting</td></tr>
<tr><td rowspan="2">Periodic progress reports</td><td>Six monthly management reports</td><td>6, 12, 18, 24, 30, 36</td></tr>
<tr><td>Annual scientific/ technical reports</td><td>12, 24, 26</td></tr>
<tr><td colspan="2">Mid term report</td><td>18</td></tr>
<tr><td colspan="2">Final report</td><td>36</td></tr>
<tr><td colspan="2">Supplementary reports/deliverables</td><td>As indicated in the list of deliverables on page 21</td></tr>
<tr><td colspan="2">List of all reports prepared within the project</td><td>36</td></tr>
<tr><th colspan="3">Cost Statements</th></tr>
<tr><td colspan="2">Periodic cost statements</td><td>12, 24, 36</td></tr>
</table>

*Figure 4.3 Reporting schedule for the FASSET project.*

Minutes summarising decisions taken and actions placed will be prepared for all progress meetings between partners. This applies both to meetings concerned with progressing the project as a whole and to meetings concerned with the progress of individual workpackages.

Management reports will be issued twice annually with the objective of providing sufficient information to the EC so that the progress of the project can be assessed relative to the work plan. If significant changes are needed regarding the work programme, schedule or deliverables, this shall be brought to the EC’s attention in the management report.

Scientific/technical progress reports will be issued once per year. These will summarise the scientific/technical progress of the project in sufficient detail to enable the EC to evaluate the achievements relative to the scientific/technical goals of the project.

The mid term report forms the basis for a formal mid-term review and assessment of the progress made. The assessment will be carried out in a meeting between the coordinator and representatives of the partners on the one hand and the EC on the other hand. In order to enable the review and assessment to take place, the mid-term report must be more elaborate than the scientific/technical progress reports.

The final report will follow a format to be provided by the EC at least six months before the end of the project. In addition, the findings of the project as a whole and in the different workpackages will be published and disseminated in the open literature to the extent found suitable. As pointed out in Section 3, a particular Technology Implementation Plan is not relevant for this project.

At the conclusion of the project, a comprehensive list of documentation produced within the project will be provided to the EC by the coordinator.

# 5 The Consortium

The contractors in the consortium are government agencies active in the field of radiation protection, public research organisations and organisations responsible for implementation of national programmes for radioactive waste management. The contractors represent the member states Sweden, UK, Germany, Spain and Finland. In addition the Norwegian Radiation Protection authority participates on a self-financing basis.

The contractors to this project can be regarded as "end-users" in different ways of the scientific developments within the project, as well as being active in performing the research itself. The contractors are familiar to the demand of the society on the kind of research carried out in the project, which is of great advantage to both the dissemination of the obtained results, and the use and test of the scientific results in real assessments. Assistant contractors provide specialist's input to the project through collaboration with the respective contractors

The partners are:

| | | | |
|---|---|---|---|
| 1 | SSI | Sweden | Swedish Radiation Protection Institute (Coordinator and WP4) |
| 2 | Kemakta | Sweden | Kemakta Konsult AB, Assistant contractor to SSI |
| 3 | SKB | Sweden | Swedish Nuclear Fuel and Waste Management Co. |
| 4 | SU | Sweden | Stockholm University, Assistant contractor to SKB |
| 5 | EA | UK | UK Environment Agency (WP3) |
| 6 | CEH | UK | Centre for Ecology and Hydrology, Assistant contractor to EA |
| 7 | WSC | UK | Westlakes Scientific Consulting Ltd, Assistant contractor to EA |
| 8 | CEFAS | UK | Centre for Environment, Fisheries and Aquaculture Science, Assistant contractor to EA |
| 9 | BfS | Germany | German Federal Office for Radiation Protection |
| 10 | GSF | Germany | German National Centre for Environment and Health (WP1) |
| 11 | CIEMAT | Spain | Spanish Research Centre in Energy, Environment and Technology |
| 12 | STUK | Finland | Radiation and Nuclear Safety Authority, Finland |
| 13 | NRPA | Norway | Norwegian Radiation Protection Authority (WP2) |
| 14 | UR | UK | University of Reading, Assistant contractor to EA |
| 15 | IPSN | France | Institut de Protection et de Sûreté Nucléaire |

The Swedish Radiation Protection Institute (SSI) will carry out the scientific and administrative coordination of the project, and carry out the coordination of WP 4. The SSI is a government agency responsible for the regulation and supervision of radiation protection issues in Sweden, including also the nuclear sector. Because of its role, the coordinator has a good network of contacts within the European radiation protection community as well as with international organisations such as IAEA, OECD/NEA and ICRP and conventions on environmental protection, e.g. OSPAR and HELCOM.

SKB is a limited company owned by the Swedish nuclear power utilities, and responsible for the development and implementation of repositories for radioactive waste in Sweden. SKB manages several research projects in the field of radiation effects of discharges from nuclear waste repositories.

The Environment Agency is the principal environmental regulator in England and Wales, with broad statutory powers to protect and enhance the environment. The Agency has specific powers to regulate the disposal of solid, liquid and gaseous radioactive wastes from sites in England and Wales. The Agency will be responsible for coordinating WP3.

The Norwegian Radiation Protection Authority is a regulatory body in the field of radiation protection. NRPA is engaged in many research projects on radioecology. NRPA will be responsible for coordinating WP2.

The German Federal Office for Radiation protection is a national authority associated with the Ministry for the Environment, Nature Conservation and Nuclear Safety. BfS is responsible for the implementing the German federal programme for management of radioactive waste from nuclear power generation. BfS is also involved in several national and international research projects in the field of radioecology.

The German National Centre for Environment and Health is a research organisation supported by the Federal German Government and the Government of Bavaria. GSF will be responsible for the coordination of WP1.

CIEMAT is a public research institution belonging to the Spanish Ministry of Industry and Energy. Within the Environmental Impact of Energy Department, The radiological Impact and the Dosimetry Programmes are acting as technical support to regulatory bodies and companies. Both programmes have wide experiences in the radiation protection field.

STUK – the Finnish Radiation and Nuclear Safety Authority is a regulatory body responsible for regulating and supervising nuclear activities and all uses of radiation in Finland. In support of the regulatory responsibilities, STUK is carrying out extensive research programmes in the field of radioecology and radiobiology.

Kemakta Konsult AB will function as assistant contractor to SSI. Kemakta will provide scientific input to WP 4, as well as assist SSI in the development of a framework for environmental assessments. Kemakta has expertise and experience from the scientific management of a number of international studies on assessments, uncertainties, and validation, in connection to radionuclide dispersion. Such studies include INTRACOIN, HYDROCOIN, INTRAVAL and BIOMOVS I.

Stockholm University, through the Department of Systems Ecology will function as assisstant contractor to SKB. The research and teaching at the Department is dedicated to the study of ecosystems and the application of knowledge thus gained to the management of natural resources. Research profiles include aquatic ecology and biogeochemistry, the ecology of benthic organisms, fish ecology, marine ecotoxicology and ecological modelling

The Centre for Ecology and Hydrology (CEH) is an independent, non-departmental government research organisation. The organisation will work as an assistant contractor to EA within its field of expertise, including environmental transfer of radioactive substances, bioavilability and vulnerability.

The Westlakes Scientific Consulting Ltd is an independent firm of environmental consultants and will work as assistant contractor to EA. Westlakes has expertise in environmental management both for radioactivity and other pollutants, assessments of toxicity in aquatic environments, and other fields.

The Centre for Environment Fisheries and Aquaculture Science (CEFAS) is a government research laboratory reporting to the Ministry of Agriculture, Fisheries and Food. CEFAS will act as an assistant contractor to EA.

The University of Reading is a multi-faculty UK higher education establishment. The Environmental Systems Science Centre (ESSC) is a post-graduate, inter-disciplinary Natural Environment Research Council (NERC) Research Unit within the Faculty of Science at the University of Reading. The ESSC is generally concerned with the application of mathematics and physics to environmental studies in a systematic way, but particularly with respect to the use of spatial data and environmental models. Its areas of expertise encompass a wide range of issues, from climate change modelling to environmental radioactivity. University of Reading will work as assistant contractor to EA.

The mission of the IPSN (Institute for Protection and Nuclear Safety) is to contribute to the control of nuclear risks and their consequences on people and the environment. IPSN carries out research and expert appraisal concerning all aspects of risk. The Institute studies all aspects of the risk posed by nuclear power stations, laboratories and industrial facilities, and by natural radioactivity. The protection of people and the environment, and the safety and security of nuclear installations are analysed in normal and accident situations.

The research and expert appraisal are linked in order to have the best available level of knowledge to hand, and to answer the question raised by risk analysis. IPSN itself carries out research in nuclear safety, occupational safety, radiological protection and radioecology and is supported by the collaboration of its foreign counterparts. The Environmental Protection Department employs around 200 staff over 7 sites in France. IPSN has extensive experience within radioecological assessments, based on field monitoring, experiments under controlled conditions in laboratory and mechanistically modelling of the behavior of radionuclides in the environment. IPSN will work ass an assistant contractor to SSI.

# 6 Other Information

## *6.1 Related projects*

In the period 1999 -2001 the IAEA will continue to contribute towards the development of policies and criteria for protecting the environment from the effects of ionising radiation. In 1999 it published the discussion document "Protection of the Environment from the Effects of Ionising Radiation" (IAEA-TECDOC-1091).

It will facilitate the exchange of information between Member States on this subject by organising Workshops (or Specialists Meetings) in 2000 and 2001. At these meetings it is expected that all aspects of the subject will be covered: principles, policies, criteria, research on the effects of ionising radiation on species, methodologies for assessment, for monitoring and for achieving compliance with criteria.

At the same time the IAEA will explore, through a series of consultants meetings, the basic rationale for environmental protection, the philosophical and ethical grounds and the development of policy.

In Canada, the new nuclear safety commission (former AECB) is in the process of developing an expanded environmental protection program. The objective is to prevent unreasonable risks to the environment. On the basis of the definition of unreasonable, “no unreasonable risk” is defined as equating to negligible or minor effects. Radiation protection criteria are going to be used to demonstrate that exposures are highly unlikely to cause effects on exposed organisms. These criteria will be used as screening values. In cases where these criteria are not met, a more detailed effect assessment has to be conducted to estimate potential population effects from the exposure. These so-called “screening criteria” will be used in a similar manner to environmental protection guidelines developed for non-radiological substances to ensure that the bases for the assessments of all emissions will be the same. The criteria will be based on radiation effects data for the most sensitive species or life stage tested with the use of appropriate safety factors. Extensive review of the relevant literature using methods developed by Canadian authorities within the field of environmental protection will precede the adoption of the criteria. Critical dose rates and expected no effects dose rates will be established for different organisms in the program. Biota dosimetry is also on-going in order to suggest appropriate RBE factors to be used in the dose calculations.

The International Union of Radioecology (IUR) is currently chairing a concerted action within the EC's DGXII IVth framework Programme entitled "Dose and effects on non-human systems". A key component of this work has been linked to defining a strategy for future studies within this research field. The IUR intends to extend this work beyond the current concerted action by building on its close ties with institutes in Eastern Europe.

A number of Russian scientists who are members of the International Union of Radio-ecologists (IUR) have a wealth of experience in disciplines relating to the exposure of the environment from ionising radiation and concomitant effects. In addition, Russian data are available which provide details of dose-effects relationships following the nuclear accident at Kyshtym in the southern Urals. Such data will be accessible through correspondence and workshops organised by the IUR. NRPA will take the responsibility to provide newly-acquired information during the course of the FASSET project.

The project "EPIC" or "Environmental Protection from Ionising Contaminants in the Arctic" has been submitted under the Fifth Framework Work Programme "Confirming the International Role of Community Research" and the Specific Call "Copernicus II". The project, if successful in attaining funds, will be co-ordinated by Per Strand of the NRPA and include the Russian partners SPA TYPHOON and the Institute of Radiation Hygiene along with the UK participant CEH. Both NRPA and CEH are involved in FASSET. The project EPIC has a number of objectives and a work structure that is broadly similar to FASSET, with the aim of promoting compatibility between the projects. EPIC differs significantly from FASSET because of its focus upon the Arctic and by virtue of the fact that the project includes a relatively large field-study component. One important rationale behind EPIC was the need to involve Russian expertise in the development of an internationally-acceptable environmental protection (from radiation) framework. The FASSET project, if successful, would benefit greatly from close ties to the EPIC project, and vice versa. The participation of the NRPA and the CEH in both projects will facilitate information flow.

### *6.2 Clustering with other projects.*

The FASSET project intends to contribute to relevant clusters set up by EC.

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