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DELIVERABLE 3:
Rationalising radioecological capacity with requirements

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The objective of the FUTURAE project is to evaluate the potential for establishing deeper and sustainable collaboration in radioecology in Europe possibly in the form of Network(s) of Excellence.

The project started in October 2006 and is to end by September 2008.

Project Coordinator: Institute for Radiological Protection and Nuclear Safety

Contractors:

Institute for Radiological Protection and Nuclear Safety	IRSN
Swedish Radiation Protection Authority	SSI
Centre for Ecology and Hydrology	CEH
Belgian Nuclear Research Centre	SCK·CEN
Research Centre in Energy, Environment and Technology	CIEMAT
University of Antwerp	UA
Radiation and Nuclear Safety Authority	STUK
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Norwegian Radiation Protection Authority	NRPA

Executive Summary

The overall objective of the FUTURAE concerted action is to evaluate the feasibility of a Network of Excellence within the 7th Framework Programme (FP7) as a mechanism of maintaining and enhancing competence in radioecology in Europe.

Previous FUTURAE deliverable reports have assessed the: (i) current levels of research capacity, human resources, infrastructure, research programmes and funding of radioecology in Europe; (ii) present and future needs of end-users of radioecological research. In this report, we bring together these two outputs and consider how to rationalise the radioecological capacity across the EU with the requirements of end users. This will form an input into the final stage of the FUTURAE CA which will make proposals on possible mechanisms to maintain and enhance competences in the area of the assessment and management of the impact of radionuclides on man and the environment at the European level.

Taken at face value, the first report of the FUTURAE project (based on responses to a questionnaire) implied that there is a wide range of radioecological expertise, sufficient funding and approximately 1000 active radioecologists in Europe. However, some questionnaire inputs were thought to be inaccurate and therefore we carried out a re-evaluation of the number of radioecologists, publications output and facilities. It was concluded that the questionnaire responses overestimated the number of active radioecologists by approximately two-fold.

Information on requirements for radioecology was identified initially from a consultation with a range of end-users in the second report of the FUTURAE project. The broad categories identified from this process were supplemented by a further review in this report of a number of recently reported or on-going initiatives which have important implications in determining the requirements for radioecology in the forthcoming years. These included: recently revised recommendations of the ICRP; OSPAR; the IAEA EMRAS programme; on-going EURATOM projects; and IUR Task Groups. The user defined requirements clearly fit into the context of European wide issues, some of which are source driven (radioactive waste, nuclear power generation; legacy issues; emergency preparedness) and others cross-cutting (protection of the environment and climate change).

The report demonstrates that there are justifiable, and increasing, requirements for radioecological research within Europe for the foreseeable future. These requirements are common across member states. A SWOT (**S**trengths, **W**eaknesses, **O**pportunities and **T**hreats) analyses highlighted issues for radioecology in Europe. Whilst Europe retains radioecological expertise in a wide range of disciplines, there are currently 'threats' to sustainability as there is considerable fragmentation occurring with the majority of organisations conducting radioecological research having comparatively small budgets and few staff. Similarly, although the first FUTURAE report indicates an adequate infrastructure, the number of facilities to conduct some key activities (e.g. low level chronic irradiation studies, farm animal transfer studies, large-scale plant uptake studies, interception studies) has declined over the last decade with few remaining. The requirement for training of future radioecologists and knowledge transfer has been highlighted by a number of fora (including a workshop held to discuss an early draft of this report). This is especially important as there will be an on-going loss of key ('Chernobyl generation') experts over the next decade. Co-

operation at European level will maximise added value and provide radioecological underpinning for those countries where there is significant fragmentation.

If a Network of Excellence is to go forward within FP7 there needs to be a spectrum of justifiable needs met by a balance of sufficient organisations with good infrastructure, excellent scientific output and fit for purpose resources. An analysis of the questionnaire responses demonstrates that there are a sufficient number of organisations meeting the above criteria who could contribute to a future Network of Excellence within Europe. Obviously, an appropriate balance between resources, facilities, areas of expertise and scientific output would be required for a successful Network of Excellence.

A consideration of whether a Network of Excellence is the appropriate instrument to meet the requirements for radioecology in Europe and how this would be best structured and managed is the objective for the next FUTURAE report and is not addressed here.

Acknowledgment

The FUTURAE Consortium would like to thank all those End Users who attended the Madrid workshop and colleagues who have responded to requests for inputs to the previous deliverables of the project.

Table of contents

1. Introduction

The overall objective of the FUTURAE concerted action (CA) is to evaluate the feasibility of a Network of Excellence (NoE) within the 7th Framework Programme (FP7) as a mechanism of maintaining and enhancing competence in radioecology in Europe. Radioecology is a multidisciplinary branch of environmental sciences which provides the underpinning science, databases, models and expertise required to support legislation, regulators and industry. Within the context of this deliverable radioecology is taken to encompass the study of the behaviour of anthropogenic and natural radionuclides in terrestrial, freshwater, marine and urban ecosystems.

Previous FUTURAE deliverable reports have assessed the: (i) current levels of research capacity, human resources, infrastructure, research programmes and funding of radioecology in Europe (Vandenhove *et al*. 2007a); (ii) present and future needs of end-users of radioecological research (Moberg *et al*. 2007). In this report we bring together the outputs of these two deliverables and consider how to rationalise the radioecological capacity across the EU with the requirements of end users. This will form an input into the final stage of the FUTURAE CA which will make proposals on possible mechanisms to maintain and enhance competences in the area of the assessment and management of the impact of radionuclides on man and the environment at the European level.

A draft of this report was discussed with external experts (the End User Group) at a workshop held 11th-12th December 2007. The notes of the workshop, attended by 20 End User Group and consortium 15 members, are recorded within Appendix A to this report. The report has subsequently been redrafted taking into account comments received at the workshop; reference to these are made throughout the subsequent text as appropriate. However, whilst the scope of this deliverable includes the demonstration of a justifiable European requirement for radioecological research it does not encompass the prioritisation of specific needs. Such a prioritisation will be conducted during the preparation of any proposal(s) in response to an open call, and subsequently during the course of any successful NoE. Furthermore, the workshop also discussed the requirements and operation of a NoE. The comments received on this are included within Appendix A and will be retained for consideration during the next phase of the FUTURAE project. All workshop participants were given the opportunity to comment on the revised draft and remarks received have been taken into account where possible in the preparation of this final report version.

2. Radioecological capacity in Europe

2.1 Overview of Deliverable 1

This deliverable (Vandenhove *et al*. 2007a) described the results of a questionnaire sent to research institutes, universities, government agencies, consultancies and industry. The questionnaire was designed to obtain information to assess the current research capacity, human resources, infrastructure, research programmes and funding of radioecology in Europe.

A total of 89 completed questionnaires were returned with replies from almost all EC member states, Norway and Switzerland. The total number of people at respondent organisations working in radioecology ranged from one to 142, with the total across Europe identified by the respondents being 845 permanent and 101 temporary staff. Approximately 60 % of responding organisations had 10 or less radioecologists with one third having less than 5 radioecologists.

The annual budget for radioecology in more than 50 % of responding organisations was less than €100k; most universities were in this category. About 25 % of the organisations had a budget between €100k-500k. Only four organisations had an annual budget exceeding €1000k. More funding is allocated to radioecology in the countries with a nuclear power programme.

Overall, the questionnaire returns suggested a good coverage of different areas within radioecology. Comparatively few respondent organisations studied marine or urban ecosystems. Similarly, some specific categories of organisms, namely birds, reptiles and amphibians were not studied by many of the respondents.

Virtually all respondents have the infrastructure to enable them to conduct analyses for alpha, beta and gamma emitting radionuclides in environmental samples. However, there was no assessment in the report as to whether these laboratories were accredited[1]. Twenty-two organisation recorded that they had facilities to conduct external gamma irradiation studies on terrestrial organisms; eleven of these also stating they had similar facilities for aquatic organisms. Five organisations (two in France, and one in each of Sweden, Norway and the UK) recorded that they had the full suite of facilities covered in the questionnaire, these being facilities for the study of (i) migration; (ii) transfer to terrestrial organisms; (iii) transfer to aquatic organisms; (iv) internal irradiation of terrestrial organisms; (v) internal irradiation of aquatic organisms; (vi) external irradiation of terrestrial organisms; (vii) external irradiation of aquatic organisms; and (viii) analytical laboratories to determine activity concentrations of alpha, beta and gamma emitting radionuclides.

The majority of responding organisations expressed the opinion that funding (and staffing levels) would remain relatively constant over the coming years.

2.2 Analysis of Deliverable 1

The objective of Deliverable 1 was to synthesise and report the information compiled from the questionnaires. Aware that some of the inputs appeared erroneous the consortium attempted to obtain more realistic information on three major issues: number of active

[1]This information was requested within the questionnaire and is considered later in this report.

radioecologists, scientific outputs and budget allocated to radioecology. Information obtained before publication of Deliverable 1 was incorporated.

Deliverable 1 indicated a large number of organisations across Europe are conducting radioecological research. Taken at face value, these organisations have a wide range of expertise, sufficient funding and have a total of nearly 1000 radioecologists. However, from personal knowledge of the consortium members this did not appear to be a true reflection of the actual number of active European radioecologists. For instance, the International Union of Radioecologists has 241 registered members from EC member states (F. Brechignac *pers. comm.*) (see also Appendix A).

Therefore, a number of the organisations who had responded to the questionnaire were contacted and asked to clarify staff numbers by identifying those individuals who are specifically involved in investigative research on the environmental behaviour of radionuclides. Of the 38 who replied 17 reduced their staff numbers compared to their original questionnaire response. The total reduction over the 37 institutes was by 321 staff members from an original total of 573. Figure 2.1 presents revised staff numbers for the ten organisations with the greatest change compared to numbers which appeared for these organisations in Deliverable 1. On the basis of the revisions by these 37 organisations, we conclude that the number of active radioecologists identified in Deliverable 1 may be overestimated by approximately two-fold. Furthermore, some of the respondents are regulatory organisations and constitute end-users who require trained radioecologists, but who may directly contribute little to radioecological research.

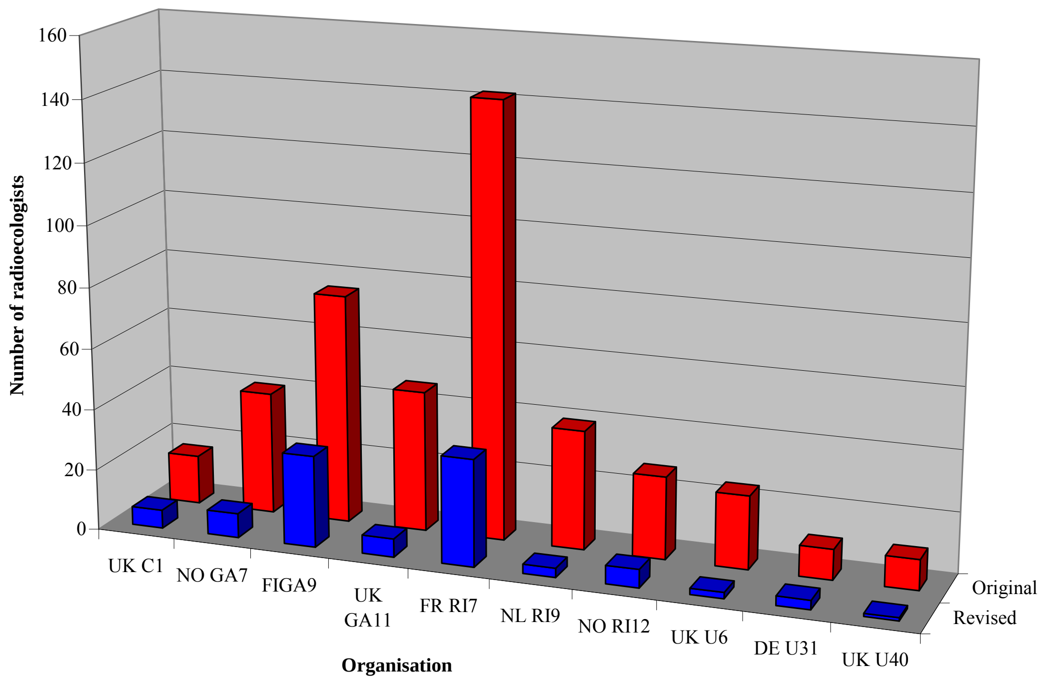

Figure 2.1. A comparison of staff numbers identified in the original questionnaire with those reported when asked to focus specifically on radioecologists for the 10 organisations with the largest changes. The organisation codes are those used in Vandenhove *et al.* (2007a): country codes DE – Germany, FI – Finland, FR- France, NO – Norway, UK – United Kingdom; organisation codes GA – government authority, RI – research institute, U – university.

The final output of the FUTURAE project, in addition to proposing a structure and objectives for a radioecological NoE may identify key contributors in Europe. Obviously, Deliverable 1 does this to some extent by identifying those organisations with comparatively large resources (scientists, infrastructure and budget) and those who make a large impact through publication. However, whilst Deliverable 1 indicates a wide area of radioecological expertise within Europe it does so at a broad level and does not identify key contributors to specific areas of radioecology nor specific skills gaps (although it does identify that some ecosystems/biota are less studied than others). To an extent this could be assessed by considering the topics of refereed publication outputs. Refereed papers, over a five year period, identified from Deliverable 1 are presented in Figure 2.2. Considering the data on staff numbers together with the personal knowledge of the consortium members and initial scrutiny of the publications lists submitted, we concluded that it was possible that not all the reported publications were refereed or came within the remit of radioecology. Therefore, in addition to being asked to reconfirm/revise staff numbers, respondents to the questionnaire were asked to do the same with their *refereed radioecological* publications numbers. In some instances, this was done in discussion with consortium members (and revised publications lists were reviewed by consortium members to ensure they contained only refereed journal papers on radioecology). Revised values are compared to those originally received in Figure 2.2. Of the 44 entries which were changed or confirmed, 21 decreased, 15 confirmed their original submission and the remaining 8 increased. Figure 2.3 compares the original and revised refereed papers presented on the basis of permanent members of staff. Some caution is required in interpreting this figure as some respondents did not confirm/ammend their original submissions. Of the 89 questionnaire respondents, 16 had a publication rate per member of permanent staff ≥5 (i.e. 1 per year per member of permanent staff over a five year period); 15 had an output rate ≤1. Contrary to what may have been anticipated, no organisation type appeared to be more or less productive than others.

The responses to the questionnaire suggest a sufficient infrastructure across Europe to enable controlled radioecological studies to be conducted. As noted above, 22 respondents stated that they had external gamma irradiation facilities. However, to the consortium members' knowledge relatively few of these have recently published in the field of chronic low level irradiation studies specifically to provide data relevant for environmental radiation protection. Furthermore, one of the irradiation facilities in Europe (the CEFAS Lowestoft laboratory) which has contributed significantly to the understanding of low-level chronic exposure has recently closed[2]. Whilst the questionnaire identifies the availability of facilities under broad headings, it does not identify specific capabilities. For instance, whilst 29 organisations stated they could conduct controlled transfer studies for terrestrial organisms – only three, to the consortiums knowledge could conduct studies with large farm animals. Therefore, to some extent, further consideration of European radioecological capacity in subsequent chapters of this report has to rely on the consortiums expert judgement/knowledge of the field in addition to utilising the questionnaire responses.

[2]CEFAS did not respond to the questionnaire.

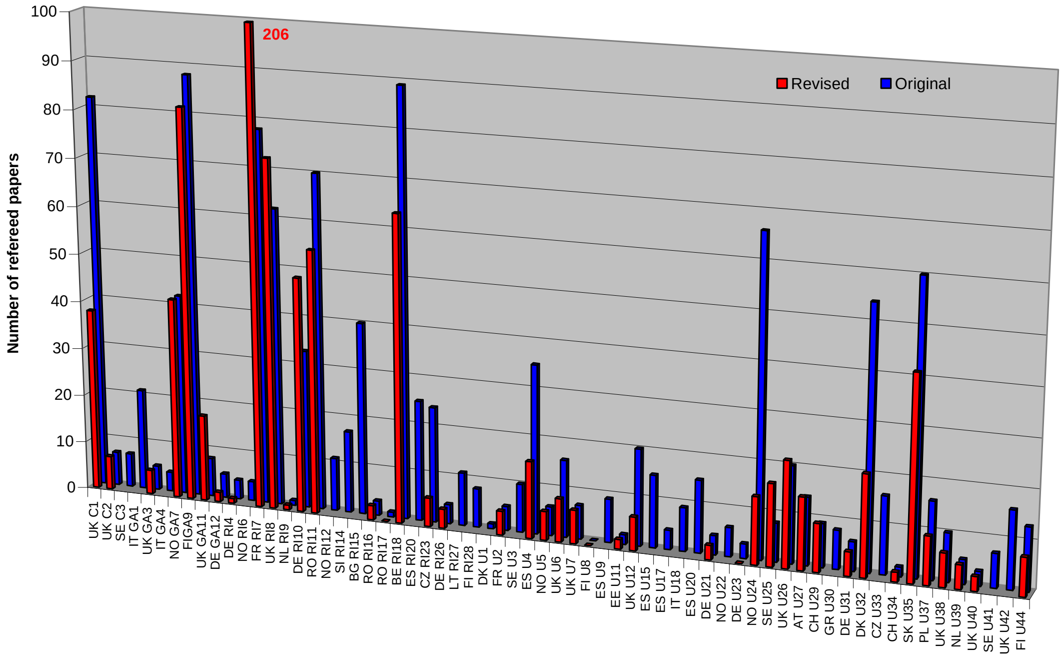

Figure 2.2. A comparison of refereed papers, over a five year period, on radioecology given in the original questionnaire with revised values when reconsidered to focus specifically only on radioecology. The organisation codes are those used in Vandenhove *et al*. (2007a).

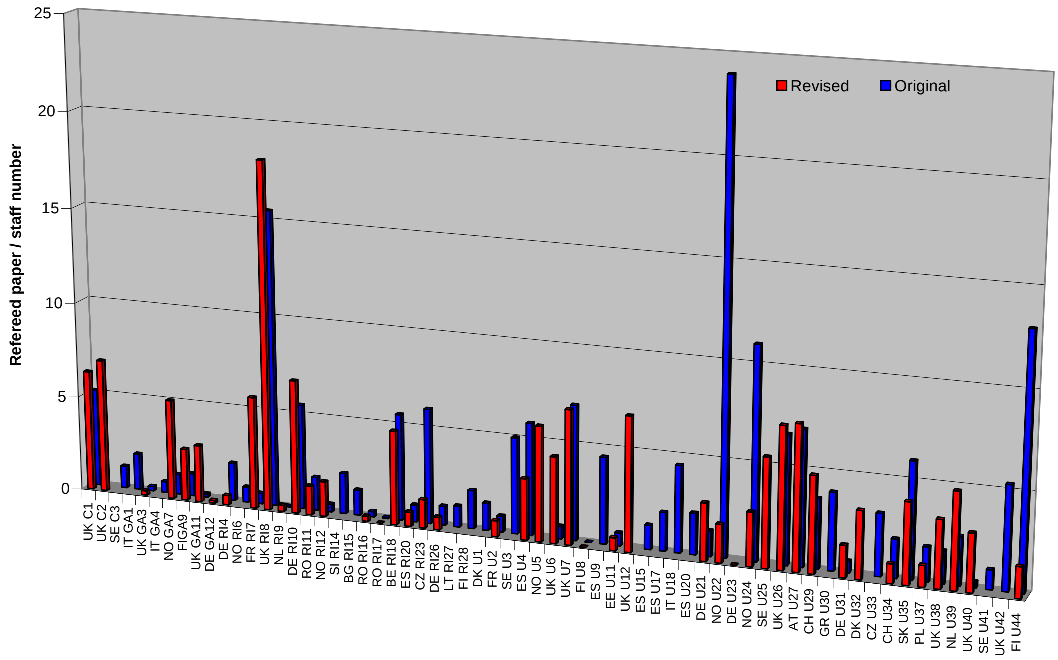

Figure 2.3. Refereed papers on radioecology per member of permanent staff over a five year period estimated from the original questionnaire revised values when reconsidered to focus specifically only on radioecology. A value of 5 refereed papers per member of staff equates to an average of one paper per radioecologist per year. The organisation codes are those used in Vandenhove *et al*. (2007a).

Whilst Deliverable 1 has provided a useful input into the subsequent activities of the FUTURAE consortium it presents an ‘over-estimate’ of radioecological resources and outputs. As commented during the Madrid workshop (see Appendix A) this is perhaps not surprising as some respondents may have seen ‘positive’ responses more likely to result in their inclusion within any NoE proposal(s).

3. Radioecological needs in Europe

3.1 Overview of Deliverable 2

This deliverable (Moberg *et al*. 2007) presented the results of a survey of radioecological needs over the next 5-10 years as identified by questionnaire and review of various reports. Twenty-seven complete questionnaires were received from 11 member states and also Norway, Switzerland and two international organisations. Regulators, industry and NGO's were all represented in the responses. The deliverable also incorporates the discussions of a workshop at which the consortium and End User Group members considered the findings of the questionnaire and associated review. Deliverable 2 concluded that the needs of radioecology identified by different groups (regulators, industry and research community) revolved around the same themes (illustrated in Figure 3.1).

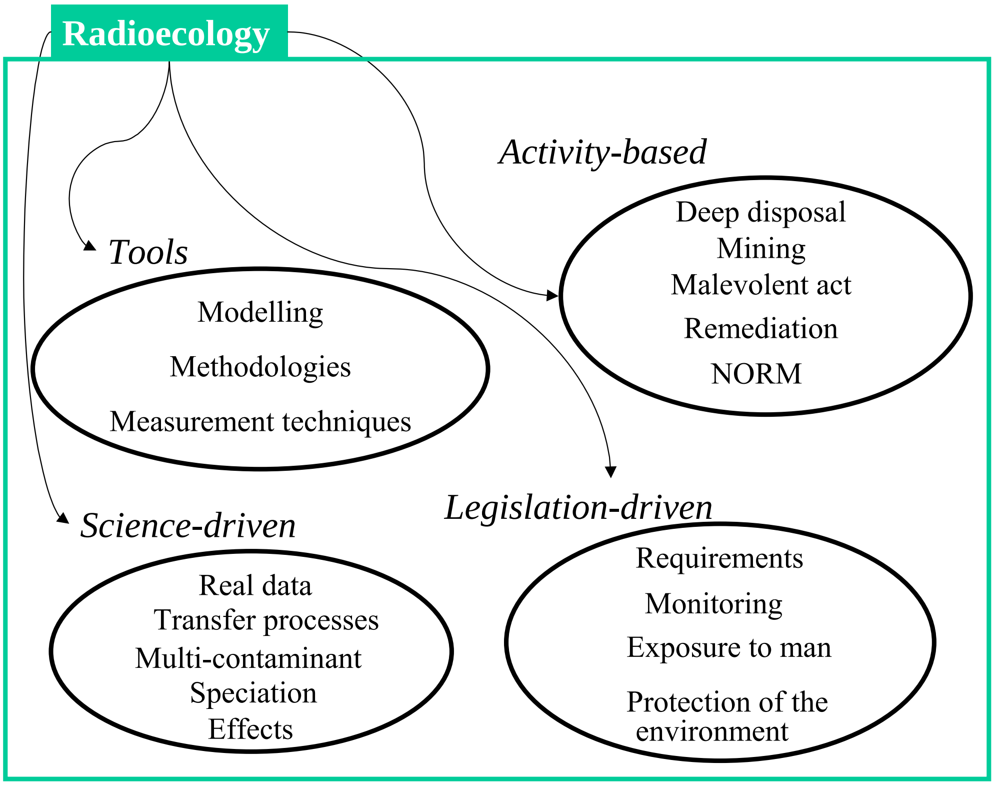

Figure 3.1. Illustration of radioecological needs identified in Deliverable 2 (taken from Moberg *et al*. 2007).

3.2 European radioecological needs – a justification

Whilst Deliverable 2 identifies many common requirements of radioecological expertise these tended to be generic, for instance, 'modelling', 'transfer processes' and 'monitoring'. There is limited detail of why these issues are important and why they should be addressed at a European level.

A number of on-going initiatives which could not be considered in Deliverable 2 have important implications in determining the requirements for radioecology in the forthcoming years; to supplement Deliverable 2 these are discussed within this subsection. In section 3.3

we put the requirements, identified in Deliverable 2 and in this section, into the context of European wide issues.

3.2.1 ICRP recommendations

The revised Recommendations of the ICRP were published in 2007 (ICRP 2007a). In the new Recommendations the ICRP state that there is a current lack of consistency at international level with respect to addressing protection of the environment in relation to radioactivity. With respect to this, in December 2007 Committee 5 of the ICRP published their draft report (*Environmental protection: the concept and use of Reference Animals and Plants*; ICRP 2007b) for consultation.

The other substantial change to the ICRP Recommendations in the context of this deliverable is:

'Abandoning the process based protection approach using practises and interventions, and moving to a situation based approach applying the same source-related principles to all controllable exposure situations, which the revised recommendations characterise as planned, emergency, and existing exposure situations.'

At this stage the possible implications for radioecology of the revised ICRP Recommendations need further discussions.

3.2.2 OSPAR

The objective of the OSPAR Convention is protection of the marine environment of the North-East Atlantic. The Strategy with regard to radioactive substances, including waste, is to prevent pollution of the maritime area from ionising radiation through progressive and substantial reductions of discharges and emissions of radioactive substances. The ultimate aim is for concentrations in the environment to be near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances. In achieving this, the following issues should be taken into account: legitimate uses of the sea, technical feasibility, and radiological impacts on humans and biota.

Even though there is not a clearly expressed need of radioecological research, OSPAR uses knowledge about the behaviour of radionuclides in the marine environment for evaluations of progress towards the strategy. In particular, OSPAR is awaiting the outcome of international efforts (e.g. the ICRP framework and EURATOM PROTECT project discussed elsewhere in this section) to develop environmental quality criteria for radioactive substances.

The Strategy includes all radionuclides discharged from nuclear and non-nuclear industrial sources into the marine environment. Currently, the focus is ongoing evaluations of concentrations and distributions of selected radionuclides in specific environmental compartments (seawater, fish, molluscs and seaweed). For nuclear sources, the monitoring programme for concentrations includes: ^{3}H, ^{99}Tc, ^{137}Cs and $^{239,240}Pu$. Priority radionuclides for non-nuclear sources include: ^{226}Ra, ^{228}Ra, ^{228}Th, ^{210}Pb and ^{210}Po in relation to the oil and gas industry. However, the OSPAR agreement on monitoring of radionuclides in the environment does not presently include radionuclides from non-nuclear industries.

The OSPAR Quality Status Report QSR (due 2010), will consider pollutant concentrations and trends for the North East Atlantic including a chapter on radioactive substances which is likely to identify gaps in radioecological knowledge relevant to OSPAR.

3.2.3 IAEA EMRAS programme

The IAEA's Environmental Modelling for Radiation Safety (EMRAS; see http://www-ns.iaea.org/projects/emras/) programme was launched in 2003 and recently (November 2007) held its final workshop. The programme consists of six working groups on model validation and inter-comparison:

- Modelling of tritium and ^{14}C transfer to biota and man
- The Chernobyl ^{131}I release: model validation and assessment of the countermeasure effectiveness
- Model validation for radionuclide transport in the aquatic system "Watershed-River" and in estuaries
- Modelling of naturally occurring radioactive materials (NORM) releases and of the remediation benefits for sites contaminated by extractive industries (U/Th mining and milling, oil and gas industry, phosphate industry, etc.)
- Remediation assessment for urban areas contaminated by dispersed radionuclides
- Model validation for biota dose assessment

A seventh working group (in collaboration with the IUR) is revising the IAEA Technical Report Series No. 364 "Handbook of parameter values for the prediction of radionuclide transfer in temperate environments" (IAEA 1994) working group.

The following is a summary of the recommendations (relevant to this report) of these working groups produced from notes of the final workshop and, in the case of the biota and TRS364 revision working groups, draft reports as available in November 2007.

A generic comment made by a number of the working group chairpersons was the lack of young scientists involved in the programme and concern over the long-term retention of knowledge with a need to ensure that there is adequate knowledge transfer to new people before many current experts retire. Knowledge management was raised by a number of EMRAS working groups as a cause for concern; there is a need to maintain datasets (especially in the current situation where few new experiments are being conducted). Note training and knowledge management needs was also highlighted by a number of attendees of the FUTURAE workshop held to discuss the draft of this deliverable (see Appendix A).

Tritium and ^{14}C Working Group

This working group recommended that there was a need for a 'healthy environmental tritium community' to respond to issues such as the ITER fusion device, concerns raised by NGOs and organically bound tritium (OBT) in fish. The working group identified a number of model test exercises which were required in the future although it was not clear if they considered that novel radioecological knowledge would be required to achieve these. The working group suggested that there was a need to develop a standard conceptual model for accidental tritium releases (different models would be required for different environmental conditions (e.g. wet and dry, hot and cold)). They also suggested that there was a requirement for knowledge on the environmental behaviour of tritium released from getter beds (storage or scavenging devices).

Iodine Working Group

The main finding of this working group was that existing models were not able to adequately predict the effect of countermeasure application and heterogeneous deposition. It was recommended that these aspects were improved.

Urban Working Group

The working group identified an extensive list of options for further modelling of urban contamination situations, in particular for deliberate and accidental events. The working group suggested two working groups for any follow-on EMRAS programme to consider the modelling of (i) long-term contaminant transfer and countermeasures and (ii) atmospheric dispersion and deposition in an urban setting. The data required for the radioecological aspects of both case scenario data and parameter values for these groups needs to be clarified.

NORM Working Group

The NORM WG listed a large number of future requirements related to modelling of natural radionuclides in a variety of different types of case studies including: new projects (e.g. new uranium facilities); existing operations; legacy sites and buildings and waste. The need for new data to provide adequate case studies or improve model parameterisation was not discussed.

Biota Working Group (BWG)

The work of the BWG has clearly demonstrated that the largest contribution to variability between model predictions, and comparison with available data, is the parameterisation of their transfer components (Beresford *et al*. in-press). Other sources are in agreement with this conclusion (Higley *et al*. 2003; Avila *et al*. 2004). In part, the variability observed is a consequence of lack of data for many organism-radionuclide combinations. It was therefore suggested that in the future a sub-group of the BWG has the objective to produce a document for biota which is equivalent to the IAEA handbook on transfer parameters for human foodchains (i.e. IAEA 1994).

The models used by the BWG predict dose rates to biota, but there is also a need to be able to determine the potential consequences of predicted dose rates. A large amount of data on the effects of ionising radiation on biota has recently been collated into the FREDERICA data base (Copplestone *et al*. in-press; www.frederica-online.org). This compilation can be used to aid decision-making on the potential impact of the predicted exposure to ionising radiation. However, the effects data available in the FREDERICA database covers only a proportion of the available scientific literature. Furthermore, to be of most use to decision makers there is a need to better evaluate the quality of much of these data to ensure that they are applicable. Whilst approaches from chemical assessments (such as species sensitivity distributions (e.g. see Garnier-Laplace *et al*. 2006)) are being adopted in trying to define dose rate benchmarks for biota it was suggested that there should also be consideration of how population modelling techniques (from other fields) might be applied to aid setting thresholds against which the degree of environmental protection can be determined.

Parameter Value Handbook Working Group

This group has reviewed and compiled transfer parameters for various process and, therefore, identified those parameters and radionuclides for which there are few and/or poor data. The text below is adapted from the draft report of the working group as available in November

2007; note not all subsections were available to the authors (e.g. semi-natural and freshwater ecosystems).

Soil-radionuclide interactions

There are evident gaps in K_d values for a substantial number of radionuclides and soil types. In some cases, values originate from a single reference suitable for screening purposes, but not for specific risk assessments. To address some of these gaps, it may be possible to use analogues taking into account distinctions in chemical form and affinity for different types of binding site that may exist between the analogue and the radionuclide of interest.

There is a requirement for more information on the reversibility of sorption and how it may change with time. However, the dynamics of the soil-radionuclide interaction may only be significant for a limited number of radionuclides (e.g. radiostrontium and radiocaesium). For radionuclides with especially low or high sorption, the dynamics may be unimportant.

Soil-radionuclide interactions are governed by multiple factors that depend on the radionuclide and on various soil properties. The main soil parameters controlling the interaction should be determined and included in models to improve the prediction of K_d. Examples are K and NH_4^+ for radiocaesium, cation exchange capacity, Ca and Mg for radiostrontium, and pH for heavy metal radionuclides and uranium.

Data for vertical migration parameters are limited and at the present it is not possible to give ecosystem specific values. Future studies should focus on the development of improved modelling techniques, based on stochastic or convection-dispersion modelling approaches, to develop robust models for the description of radionuclide vertical migration in soils and improve the database of existing values for different environments and soil characteristics.

Crops - foliar interception, soil uptake and translocation

Data for interception are available for only a few elements, such as caesium, strontium and iodine; single estimates are available for a few other elements. For the majority of elements, interception is derived from data for analogue elements based on the assumed chemical form and valency of the element. Due to the negative charge of plant surfaces the radionuclide retention of cations by the leaf is thought to be enhanced. However, existing data are insufficient to provide a reliable quantification of this.

There are few data on translocation factors in chronic contamination situations simulating sprinkling irrigation distributed throughout the vegetative cycle of a crop.

There is a need for research on the behaviour of radionuclides in fruit crops to drive model development; research should focus on understanding the key processes. Experiments undertaken to validate existing models should be directed towards the provision of time-dependent data on the distribution of radionuclides in fruit crops rather than to the provision of datasets comprising single end-points such as concentration in fruit.

There is a clear lack of soil-to-plant transfer factor data for Po, with very few sources reporting adequate Po data. For most crop groups transfer factor data for Po were scarce or non-existent (Vandenhove *et al*. submitted a,b).

Domestic animals

Available data for the transfer coefficient of radionuclides to farm animal products (where the transfer coefficient is the ratio of the fresh weight radionuclide activity concentration in an animal product (Bq kg^{-1}) to the radionuclide daily intake (Bq d^{-1})) were collated. For approximately 50 % of the required (>380) radionuclide-animal product combinations no transfer coefficient data were available. Of those combinations for which values could be recommended, less than 14% were based upon more than five studies.

The review investigated the suggestion (e.g. by Ng *et al*. 1982, Beresford *et al*. 2007a) that the concentration ratio (the ratio of the fresh weight radionuclide activity concentration in an animal product (Bq kg^{-1}) to the dry weight radionuclide concentration in the diet (Bq kg^{-1})) would be a more robust and generic parameter than the transfer coefficient. For most radionuclides the concentration ratio data complied varies little between the species considered (sheep, goats, cattle, horses and poultry). Therefore, concentration ratios derived for one species could be applied to another. However, unfortunately, many authors who report transfer coefficients do not provide the information required to estimate concentration ratios.

Whilst the revised version of IAEA (1994) will contain recommendations, where possible, for the gastrointestinal absorption coefficient of radionuclides in farm animals it has not considered other important aspects such as biological half-life and transfer to edible tissues other than muscle.

Radionuclides identified in other sections of this deliverable as being of interest are often amongst the more poorly studied (e.g. ^{36}Cl, ^{237}Np, ^{99}Tc, U-isotopes, Th-isotopes, ^{241}Am, ^{59}Ni, ^{94}Nb, ^{60}Co, etc.) or have not been considered (e.g. ^{252}Cf, ^{192}Ir) within the revised IAEA handbook. The same is likely to be true for other transfer parameters.

Future plans

During the course of the final workshop it was stated that from the IAEAs perspective any future follow-up EMRAS (likely to start November 2008) would be aligned to the revised Recommendations of the ICRP to aid the IAEA in preparation of a forthcoming revision to its Basis Safety Standard. In this context it was proposed that there would be four areas within a follow-up programme:

- Planned exposure – inter-comparison of model predictions for mixed environments/radionuclides.
- Existing exposure – to include continuation and enlargement of the NORM WG.
- Exposure in emergency situations – potentially considering 'radioecological sensitivity' (see section 3.3.5).
- Continuation and enlargement of the Biota WG, with the possible preparation of a handbook on biota exposure.

3.2.4 PROTECT CA

The EURATOM funded PROTECT CA, which runs concurrent to the FUTURAE CA, has the objective of (i) evaluating the different approaches to protection of the environment from ionising radiation and will compare these with the approaches used for non-radioactive contaminants; (ii) providing a scientific justification on which to propose numerical targets or standards for protection of the environment from ionising radiation. The CA has six months before it makes a final report; however, it has provided the following input into this FUTURAE deliverable based on work so far.

Activities in the first year have focussed on a review of approaches to protection of the environment from ionising radiation and chemicals (Hingston *et al*. 2007). Recommendations arising from this work appropriate to FUTURAE are:

- Protection should focus on the population level although it should be noted that individuals may need to be considered e.g. those that are rare or endangered species

- The protection goals should be translated into measurable targets and advice provided on tolerable risks associated with these endpoints
- Developments in radiological environmental protection should take account of developments in chemicals environmental protection. Harmonisation between radiological and chemical approaches should be aimed for and this should be possible for protection goals at least.
- To determine benchmark dose rates. PROTECT encourages the use of approaches accepted in the setting of chemical benchmarks (i.e. species sensitivity distributions and assessment factors).
- Once thresholds or some other methods of environmental protection have been agreed, methods for demonstrating compliance should be evaluated.

In Beresford *et al*. (2007b) the PROTECT consortium began to compare the available models to demonstrating protection of the environment from ionising radiation. Three models (RESRAD-BIOTA (http://web.ead.anl.gov/resrad), EA R&D128 (Copplestone *et al*. 2001;2003) and the ERICA Tool (Beresford *et al*. 2007c)) which all use a tiered assessment approach and are readily available for third parties to use, were applied to a scenario based loosely upon data from an assessment of discharges into a river conducted within the United Kingdom. The models all predicted that dose rate screening levels (which vary between the approaches) would be exceeded. However, different limiting radionuclides and organisms were identified by each model with maximum predicted dose rates ranging over two orders of magnitude. Subsequent investigation of the model parameters showed this to be due to differences in the values for concentration ratios and sediment-water distribution coefficients. This supports the conclusions of the EMRAS Biota Working Group above that variation in the transfer components between the available models contributes most to variability in predicted dose rates.

3.2.5 IUR Task groups

Reports of three IUR task forces have recently become available. Whilst these were considered by FUTURAE in Moberg *et al*. (2007) their main findings are briefly summarised here to aid the overall discussion.

Radioecology and waste (IUR 2006a)

An overview of the behaviour of ^{14}C, ^{36}Cl, ^{99}Tc, ^{237}Np and ^{238}U was presented for terrestrial and aquatic environments. Research requirements were listed for all five radionuclides, and Tc and Np were highlighted as elements for which there were few available data. It was also recommended that a similar overview was required for other radionuclides relevant to waste repository assessments, namely: ^{59}Ni, ^{79}Se, ^{94}Nb, ^{129}I, ^{226}Ra, ^{239}Pu, and ^{241}Am.

Radioecology in a multi-pollution context (IUR 2006b)

Both man and the environment are exposed to multiple pollution sources from industry, agriculture, traffic, etc.. This has resulted in pollution scenarios where organic and inorganic (including radionuclides) pollutants are present simultaneously; these may interact to produce combined impacts on biodiversity and ecosystem functioning. The presence of mixtures of contaminants (or other stressors) may influence pollutant behaviour and also the response of organisms to exposure. The environmental behaviour and effects induced by contaminants has generally been studied for individual pollutants (i.e. single stressor studies). Understanding multiple stressors is particularly challenging when their combined effect cannot be predicted based on evidence from single-stressor studies (i.e. if interactions that cause non-additive effects occur). Whilst few studies have considered radionuclides in a representative multi-stressor context, there are many examples where they occur in association with other contaminants (e.g. discharges from the nuclear industry, and contamination following extraction and processing of NORM). There is a need to develop and test a general set of methodologies to provide a confident basis for the prediction of multiple stressor effects.

The report of the task group identified (from questionnaire responses) priority requirements for future research: understanding how the multi-pollution context affects the behaviour of individual pollutants; additive and synergistic effects; responses of biota to both radioactive and chemical stressors; optimised remediation strategies for multipollution scenarios.

Radiological protection of the environment (IUR 2006c)

The IUR has taken on the role of identifying and filling data gaps and uncertainties with respect to radiological protection of the environment. To begin this task, a research expertise questionnaire was initiated which IUR members and other interested parties were invited to complete. On the basis of opinions provided by 41 respondents key knowledge gaps were identified and categorised in four areas:

- Gaps in the assessment frameworks to demonstrate protection of the environment from ionising radiation
- Transfer of radionuclides in the environment
- Effects of ionising radiation on biota
- Dosimetry

Many of the specific requirements identified were related to model validation and inter-comparison, and assessment/understanding of uncertainty. Others were rather generic (e.g. understand the processes that determine how radionuclides transfer through an ecosystem; understand the role chemical speciation plays in determining how radionuclides transfer through ecosystems).

3.2.6 EURANOS

The EC EURATOM funded EURANOS project (see http://www.euranos.fzk.de) is focussed on nuclear and radiological emergency management and rehabilitation strategies. As the project is nearing completion it has been consulted during the preparation of this report. The following (potential) requirements were identified:

- Combine monitoring information with modelling
- Potential requirement to review the data base of the radioecological models to determine if they are still state of the art
- Research into the behaviour of radionuclides in inhabited areas

3.3 Putting radioecological needs into a European context

European states face many common issues with regard to environmental radioactivity. For instance, the world-wide debate on future energy sources is increasing the likelihood of new nuclear power plants (plants are currently being built in Finland and Romania, with construction to start soon in France) and a number of member states have to address legacy issues associated with waste and contaminated sites. Similarly, changes in international recommendations potentially impact on legislation, regulation and industry across the EC.

In this subsection we try to put radioecological needs (which encompass planned existing and emergency exposure situations) into context with these European wide issues. Some of these issues are source related whilst others are cross-cutting.

3.3.1 Radioactive waste

All European states face the problem of long-term waste storage although this is greatest in those states with a nuclear power programme. Radioecology has a role to play in relation to safety assessments focusing on the long-term behaviour of radionuclides potentially released into the biosphere. Much of the previous and on-going research related to waste repositories is focused on the behaviour of radionuclides in the geosphere (e.g. see currently EC funded projects: NF-PRO (www.nf-pro.org); FUNMIG (www.funmig.com); PAMINA (www.ip-pamina.eu)).

The Fifth Framework projects BIOCLIM and BioMoSA (see http://www.andra.fr/bioclim/) had an emphasis on biosphere, and some recommendations of these projects are subsequently being considered in the BIOPROTA (http://www.bioprota.com/) project, which includes both regulators and operators. BIOPROTA is addressing the key uncertainties in long-term assessments of contaminant releases into the environment arising from radioactive waste disposal. To date activities have predominantly been inter-comparison modelling exercises of parameters such as accumulation in soil and ^{14}C dose assessment, and site characterisation issues (all reports of completed activities are available from the website). Future activities will consider U-series modelling, non-human biota assessment methods, ^{79}Se, non-radioactive risks (chemical toxicity) and behaviour in the geosphere-biosphere interaction zone. The priorities identified by BIOPROTA from model inter-comparison exercises are in agreement with the research requirements identified by the IUR task group (IUR 2006a). Priorities identified by the BIOPROTA group have led to subsequent funding of radioecological research (e.g. Cl transfer to farm animals).

Whilst the overall aim of radioecological research on waste repositories is to improve estimation of exposure of humans and non-human biota, the results of properly parameterised models will also feedback into the process of design and management.

3.3.2 Protection of the environment

The need for a system to protect the environment from ionising radiation has, over the past decade, been recognised internationally. The ICRP has recently addressed environmental protection as an element of its revision of recommendations (ICRP 2007) and environmental protection is referred to in the draft revision of the International Atomic Energy Agency's (IAEA) Basic Safety Standards (BSS). Within Europe only the UK, Sweden and Finland currently regulate specifically to protect the environment (from radioactive releases) rather than relying on previous ICRP statements (Hingston *et al*. 2007). The recommendations of the ICRP and changes in the IAEA BSS are likely to lead to a change in this situation. As more member states regulate specifically for the environment in forthcoming years, regulators and industry will require the support of radioecological expertise. Scientific requirements in this cross-cutting area have been outlined in a number of sub-sections of section 3.2 above.

3.3.3 Nuclear power generation

The potential for the future building of new nuclear power stations within a number of member states appears to be increasing. If this does happen, then there will be a continuing, or potentially increasing, requirement to have people trained in sampling, analyses and modelling to support monitoring and routine assessment. Radioecological expertise will also be required in safety case assessments during the planning phase of any new power plants.

The likelihood of new build raises the question as to whether this leads to any new radioecological requirements especially since discharges from any new reactors will probably be lower than existing reactor designs[3]. However, some reactor types being considered may have differing discharge profiles. For instance, consideration of the environmental behaviour of ^{3}H and ^{14}C gains importance in safety assessments for CANDU reactors; a second CANDU reactor recently entered service at Cernavoda Romania (Romania plans to build a further two CANDU reactors) and this reactor type is one of those being considered in the UK (see http://www.hse.gov.uk/newreactors/reactordesigns.htm[4]). Similarly, the safety overview for EPR reactor within the UK suggests a potential 10 % increase in gaseous ^{14}C releases compared to 'a typical existing 1300 MWe unit'; all other listed gaseous and aquatic releases are predicted to be the same or to reduce (AREVA-EDF 2007).

The ITER fusion device is also to be constructed in southern France. The ITER device will use ^{3}H (an estimated 16 kg of externally supplied ^{3}H will need to be supplied throughout the life of the device (http://www.iter.org/a/index_nav_4.htm[5])). The device will produce activation products including isotopes of C, Be, Fe, Cu and W (see http://www.iter.org/a/index_nav_4.htm). There are comparatively few data on the environmental behaviour of some of these radioisotopes.

The current potential for expansion in nuclear power and associated rise in price of uranium-ores means that many countries are considering increasing their mining and milling activities (either at new or previously closed sites). Whilst most of this is likely to occur outside of the EC, some member states may begin/increase activities in this area. As noted above, the IAEA EMRAS Parameter Value Handbook working group highlighted a lack of transfer parameter values for NORM radionuclides.

3.3.4 Legacy issues

A number of human activities have led to the legacy of radioactively contaminated land in Europe (currently there is not a consistent definition of what constitutes 'radioactively contaminated land' across EU member states). These sites should be regarded as interventions under the existing EC BSS (EU 1996). Some of these are associated with contamination by NORM due to a range of industrial activities. Other current issues being addressed by member states are associated with the decommissioning of nuclear sites and the changes in use of land previously occupied by armed forces. The latter is again NORM contamination, ^{226}Ra, as a consequence of historical luminising operations and equipment disposal (EA 1999; Vandenhove 2000). Radionuclides having been identified as relevant to contaminated land are: ^{3}H; ^{14}C; ^{55}Fe; ^{60}Co; ^{63}Ni; ^{90}Sr; ^{99}Tc; ^{134,137}Cs; ^{226}Ra; ^{232}Th; ^{235,238}U; ^{241}Am; ^{238,239,240,241,242}Pu (Baker *et al*. 2000). Few of these are amongst the most well studied radionuclides in terms of environmental behaviour (see section 3.2.3 above) and the chemical forms considered may not be appropriate to assessments of contaminated land.

There are numerous (European) industries and processes that produce residues containing NORM (e.g. mining and milling of metal ores; production of including coal, oil and gas; production of industrial minerals, including phosphate). Until relatively recent times, there

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[3] For instance, this is the case for the Olkiluoto 3 (European Pressurised Water Reactor (EPR)) reactor currently being constructed in Finland (T. Ikäheimonen (STUK) pers. comm.).

[4] Accessed 15/11/07

[5] Accessed 20/11/07

was little awareness of NORM as a potential environmental and human health issue. In many situations, past operations involving the handling of wastes and residues containing NORM were not under regulatory control. This has three major implications:

- many countries now have problems with legacy wastes, particularly from mining and mineral processing operations;
- for many legacy sites, the currently available data do not provide a good basis for modelling studies, because monitoring of such sites and their surroundings has not been required in the past.
- misuse of NORM wastes, or legacy sites, may result in unacceptable radiation exposures to members of the public (e.g. construction of housing using uranium mining or mill wastes, or building homes on former NORM containing mine sites).

In evaluating options for management of a legacy site, models can be used as an aid in assessing the health and environmental impact of the site in its current and remediated state. Although because there was little attention paid to the characterisation of the sites or the design of facilities models are not easy to apply. Whilst, the most commonly used techniques used in the remediation of contaminated land are in essence civil engineering practices (e.g. excavation of contaminated soil; capping; vertical and horizontal in-ground barriers) (IAEA 2000; IAEA 2002) radioecology can contribute significantly to the optimisation of the implementation of these techniques. There may also be a need to assess the mobility of radionuclides following such practices. Furthermore, radioecology may be able to contribute to the further development of phytostabilisation or phytoextraction (use of plants to remove contamination) and bioremediation (e.g. use of soil fungi/bacteria to immobilise contaminants in soil). However, opinion differs on the useful exploitation of phytoextraction to remediate sites contaminated by radioactivity (Beresford 2006, Vandenhove & Van Hees 2004).

A potential challenge contaminated land presents to radioecologist is the identification and quantification of unusual pathways of exposure of humans via wildlife (see Beresford 2006 for examples).

3.3.5 Emergency preparedness

The EURATOM funded projects STRATEGY (see http://www.strategy-ec.org.uk/) and EURANOS (see http://www.euranos.fzk.de) have recently reviewed and evaluated available countermeasures, and produced countermeasure compendia (Beresford *et al.* 2006) and handbooks for managing contaminated food productions systems (Nisbet & Rice 2006) and inhabited areas (Brown *et al.* 2007). During the course of this work a few suggested countermeasures were identified as requiring further development/proof of effectiveness before they could be recommended for use. The EURANOS handbooks and compendia present an up to date generic overview of the state of understanding. However, any emergency situation is by nature individual, and maintenance of radioecological knowledge is required to assist in the optimisation of countermeasure/remediation strategies to the specifics of the ecosystems affected.

Within FUTURAE Deliverable 2 (Moberg *et al.* 2007) one of the potential future requirements identified was the optimisation of monitoring (and use of the subsequent results) in emergency management. We note that there is currently a FP7 call which seeks to address this (Fission-2008-3.3.1: Optimal approaches for monitoring).

Within section 3.2.2 we noted that the IAEA had suggested one aspect of the follow-up programme to EMRAS would be to consider radioecological sensitivity in the context of emergency management. Previous EURATOM funded projects made an investment in beginning to develop this concept (Strand *et al*. 1999; Beresford *et al*. 2002; Howard *et al*. 2002; Wright *et al*. 2002) predominantly for radiocaesium, with some consideration of ^{90}Sr, by combining spatially implemented radioecological models with data on food production and human consumption habits. Work was also begun to incorporate spatially implemented radioecological models within optimising decision support systems (Cox *et al*. 2005). The potential benefit of this investment has not subsequently been realised. Such approaches would have aided post-Chernobyl management within member states.

The need to be able to address potential malevolent acts was identified by a number of stakeholders earlier in the FUTURAE project (Moberg *et al*. 2007). Associated with these concerns are potential requirements to be better able to model the behaviour of radionuclide transport and behaviour in urban systems suggested by a number of the organisations/projects reviewed in section 3.2 above. International concern over the potential malevolent, terrorist, use of radioactive sources was triggered by the attacks of September 11th 2001 (IAEA 2003b). Of particular concern is that a radioactive source together with conventional explosives will be used as a radiological dispersal device (RDD) or 'dirty bomb'.

Worldwide there are thousands of radioactive sources of significant strength used for medical, industrial and academic applications, including: medical and industrial radiotherapy, food and pharmaceutical product sterilisation, oil exploration teletherapy etc.. Radionuclides of particular concern due to their long half-life, radiotoxicity and widespread use are: ^{241}Am, ^{252}Cf, ^{137}Cs, ^{60}Co, ^{192}Ir, ^{238}Pu and ^{90}Sr (Sohier & Hardeman 2006). Strong sources of ^{90}Sr are commonly used as thermoelectric generators in navigational systems in the former Soviet Union often in remote locations (Ferguson *et al*. 2003). Tens of thousands of sources are estimated to be 'orphaned' (lost from system of control) in the EC, USA and former Soviet Union countries (Ferguson *et al*. 2003; Sohier & Hardeman 2006).

The major focus with respect to this issue has rightly been to promote security and safety with respect to radioactive sources ('cradle to grave planning') and recovery of orphaned sources (e.g. IAEA 2003b; 2004). There has been some focus on the behaviour of radionuclides released from RDDs and the applicability of countermeasures to these radionuclides (e.g. by the EURANOS project). However, there has been little consideration of the behaviour of radionuclides (including physiochemical form) which may potentially be released from RDDs into the environment (for instance into water courses), instead the focus has been on consideration of urban areas.

3.3.6 Climate change

As for a range of other environmental contaminants, many aspects of radioecology are potentially vulnerable to scenarios of climate and environmental change outlined in the relevant international assessments (ACIA 2004; AMAP 2003; IPCC 2001). Note here we are not discussing the long-term climate change scenarios which have to be incorporated into assessments of, for example, deep waste repositories, but the generally acknowledged on-going climatic changes. Some European countries have already implemented national projects for the assessment of the impacts of climate/environmental change on certain facilities (for example, the UK NIREX study: *Impact of Sea Level Rise on the Fate of Radionuclides at Contaminated Nuclear Sites* (NIREX 2005)).

Climate induced changes in stressors such as UV exposure and exposure to organic pollutants (for both humans and biota) places emphasis on radioecology within a multi-pollutant context. The stability of organic soils is also of relevance (see, for example, IPCC 2001) as such soil types constitute a primary sink for radioactive contaminants across much of Europe. Parameters used to describe the behaviour of many radionuclides in such soils can be expected to change due to the changing climate.

Northern European regions have been in focus recently, for political and strategic reasons, as an area rich in resources where accelerated development is likely in the coming years. These regions are recognised as being most vulnerable to climate/environmental change and are likely to exhibit the most rapid and drastic changes. Potential areas of radiological concern relate both to sources of radioactivity and to the environmental behaviour of radionuclides.

A number of significant, or potential, sources of radioactivity exist in the northern regions. A good example is the situation at the coastal nuclear legacy facilities on the Kola Peninsula (northwest Russia) which contain amongst the largest inventory of nuclear waste in the world. For instance, some 22500 nuclear fuel assemblies (490 PBq), an estimated 400 m^3 of liquid radioactive waste (>4.5 TBq) and 17600 m^3 of solid radioactive waste (0.7 PBq) are stored at the Andreeva and Gremikha Bay facilities (Grigoriev 2004). International remediation efforts are underway; both bases are in such an advanced state of disrepair and pose a significant and longstanding risk to the local and regional environment. A primary agent of degradation of these facilities has been the harsh climate they are exposed to. The environmental risk associated with such facilities will be further enhanced due to factors outlined in various climate assessments for instance: accelerated and enhanced coastal erosion and reduction in coastal stability; the impact of increased precipitation and runoff on contaminated soils; inundation; impacts of severe weather/storm surge on coastal facilities and floating waste storages.

Potential impacts of climate scenarios on the transport of radioactive contaminants to the northern regions have been identified and the results highlight the need for further work on this topic (see AMAP 2003).

Predicted environmental and climate change could also significantly change usage of the northern regions; there may be the possibility of transporting nuclear materials along the now ice-free northern passage. Russia has indicated an interest in developing nuclear industry in the area, primarily in relation to floating nuclear plants the keel for the first was laid in April 2007, in collaboration with China.

Another activity expected to affect the radiological situation in northern areas is increased exploitation of oil and gas resources which are becoming more accessible due to the retreat of sea ice. There is a lack of knowledge of how the associated NORM wastes would behave in these environments.

The Arctic Monitoring and Assessment Programme concluded that ''*any substantive increase in ^{222}Rn evasion due to warming/permafrost melting would have a widespread and substantial (doubling or tripling) effect on the radiation dose*'' (AMAP 2003).

There is a need for more research into the potential effects of climate/environmental change on radiation doses for humans and biota, especially within the context of an evolving multi-stressor environment. Climate/environmental change will also impose an added level of uncertainty to a wide range of factors and parameters used to describe the fate and behaviour of radioactive contaminants in the environment. Whilst much of the above discussion has considered northern Europe, climate change is likely to have implications for other regions (e.g. increased resuspension risk in southern areas in conditions of prolonged drought). As a consequence of this, effort is required towards developing modelling (and monitoring) strategies that take into account uncertainties imposed by changes in either climate or environment.

3.4 Radioecology in a broader environmental perspective

Radioecology became a strong environmental discipline over the period late 1950's-1990's developing methodological and modelling approaches and generating fundamental understanding which was well advanced in comparison to the developments in other emerging disciplines of environmental chemistry and toxicology. However, today environmental chemistry and toxicology is an integrated, mature discipline and major progress has been made over the last decades towards a better understanding of the fate of pollutants in the environment and their impact on biological systems and ecological integrity as a whole. Historically, the disciplines have developed separately, in part because of the anthropogenic focus of radioecology (driven by recommendations of the ICRP etc.) compared to the more environmental focus of chemical ecotoxicology.

The majority of this deliverable has considered radioecology in isolation from other areas of environmental science. In this subsection we consider the interactions between radioecology and other areas of environmental science.

Risk assessment

Environmental chemical pollution can be roughly divided into three categories, organic chemicals, heavy metals and radionuclides. Although these have been studied by separate groups much of the fundamental principles related to the fate of pollutants in the environment are similar, especially as many radionuclides are heavy metals. In terms of mode of action there are, of course, clear differences.

Consideration of transfer is integral for all pollutants, however, the way in which the effects of environmental stressors on the environmental fate, biological effects and ecological impact is treated tend to be different. For example, the integration of information on the chemical speciation and biological availability of toxicants is a major feature of current research and future regulation in the environmental risk assessment of metals. Whilst such processes are acknowledged to be important within the radioecological community and have been the focus of considerable research (e.g. Salbu 2007; Gillett *et al.* 2001; Vandenhove *et al.* 2007b; Beresford *et al.* 2000), their inclusion within assessment models is generally lacking (in-part the suggestions of the IAEA to restart consideration of radioecological sensitivity may begin to address this (see sections 3.2.3 and 3.3.5 above)).

In addition to being able to learn from each other we also need to be able to assess mixtures of pollutants (radioactive, chemicals and potentially others) as discussed above (section 3.2.5). Therefore, ecological risk assessment will need to adopt an integrated approach. Environmental quality criteria are generally developed for organic contaminants and heavy metals using a more or less common framework, but recognising the important differences between classes of compounds in terms of physical, chemical and biological behaviour. Recent EURATOM projects (FASSET, ERICA and PROTECT) which have considered environmental protection of the environment have tried to develop approaches comparable with those used for chemical assessments. They have also applied techniques to define, for instance, screening values for use within assessments, which were originally derived for chemical assessments (e.g. guidance as outlined in the EC Technical Guidance Documents[6]).

Radioecology in other disciplines

Radionuclides have important applications in other areas of environmental sciences. A number of radionuclides are used as tools to trace environmental processes such as the biogeochemical cycle of carbon, soil erosion processes, the dynamics of sedimentation processes, aquifer and groundwater flow, ice transit time scales, estimation of energy budgets in wildlife populations, and the organisation of food-webs (e.g. Papastefanou, 2006). These different research topics illustrate the importance of radioecological expertise beyond the area of radioprotection and risk assessment and the need for a continued support and development of this expertise for application in different fields of environmental sciences.

[6] http://ecb.jrc.it/home.php?CONTENU=/DOCUMENTS/TECHNICAL_GUIDANCE_DOCUMENT/

4. Discussion

A strength of radioecology within Europe over the last two decades has been the degree of collaborative research enabled by EURATOM programme funding. Recent EURATOM projects which have demonstrated the effectiveness of such collaboration are the ERICA project (Larsson in press), which developed an approach and associated software tool for environmental assessment, and the FARMING-STRATEGY-EURANOS projects considering countermeasures/remediation strategies (see Nisbet *et al*. 2005). Both examples gained much added benefit from European level collaboration and their outputs have been more effectively taken forward as a consequence.

A consultation with end-users and review of recent initiatives has clearly demonstrated justifiable requirements to maintain radioecological expertise and research within Europe for the foreseeable future to meet the needs of regulators, industry, respond to any changes in legislation, demonstrate compliance with existing/future regulation and respond to any unplanned events. These requirements are common across many member states associated with source-driven (nuclear power generation, waste issues, emergency management and legacy issues) and cross-cutting (environmental protection and climate change) needs. Consequently, there would be added value in co-ordinating the research required to meet these needs.

Whilst Europe retains radioecological expertise in a wide range of disciplines there is considerable fragmentation occurring with the majority of organisations conducting radioecological research having comparatively small budgets and few staff. Similarly, although FUTURAE Deliverable 1 (see section 2) indicates an adequate infrastructure the number of facilities to conduct some key activities (e.g. low level chronic irradiation studies, farm animal transfer studies, large-scale plant uptake studies, interception studies) have declined over the last decade.

A consideration of whether a Network of Excellence is the appropriate instrument to meet the requirements for radioecology in Europe is the objective for Workpackage 4 and will not be addressed here. However, if a NoE is to go forward within FP7 there needs to be a balance of sufficient organisations with good infrastructure, excellent scientific output and fit for purpose resources. We have attempted to determine whether the EU contains organisations which may be able to achieve this balance on the basis of criteria derived from Deliverable 1 and its underlying questionnaire response database. Table 4.1 identifies organisations on the basis that they meet at least one of the following criteria:

- Have 10 or more permanent staff who can be classified as radioecologists;
- Have a refereed journal publication output of 5 or more papers per member of permanent staff over a 5 year period (i.e. >1 paper per member of staff per year);
- Have facilities to conduct controlled transfer studies (terrestrial or aquatic);
- Have facilities to conduct radiation effects studies (terrestrial or aquatic);
- Have accredited radioanalytical laboratories;
- Have an annual budget devoted to radioecology in excess of €500k.

Organisations meeting a given criteria are identified by shaded cells within the table. If responding organisations did not answer questions on staff and publication numbers or budget then they were not considered for inclusion in Table 4.1. Those organisations who did not respond to the facilities questions were assumed (on the basis of the consortium member knowledge) not to have such facilities. As noted in section 2.2 no confirmation of staff numbers or radioecological referred publications was received from some organisations; these organisations have been included (and identified) in Table 4.1 if they met the criteria from their initial submission but these inputs may be less reliable.

Of the 89 organisations responding to the FUTURAE questionnaire, 46 fulfilled at least one of the criteria for inclusion in Table 4.1. Only one organisation met all the criteria for inclusion. There are few well resourced institutes (i.e. in terms of staff numbers and budget) and not all of these meet the other criteria.

Table 4.1 demonstrates that there are sufficient organisations who could contribute to any future NoE within Europe. Obviously an appropriate balance between resources, facilities, areas of expertise and scientific output would be required for a successful NoE. In addition to criteria analysed within Table 4.1, there are additional attributes which may be beneficial to a NoE, for instance organisations with radiobiological, ecotoxicological, ecological expertise (etc.) in addition to radioecological expertise would provide added value to a NoE. A full analysis of requirements and availability of infrastructure to meet these associated disciplines is not possible on the basis of available information. However, there are clearly identifiable scarce, skills and infrastructure resources which would be needed in a NoE if it were to successfully address some of the identified requirements, including low level chronic irradiation and large animal experimentation facilities, and expertise in urban radioecology.

Further exploration of how any NoE would best be structured and managed is the objective of Workpackage 4 of FUTURAE and inappropriate within this deliverable. Workpackage 4 will consider how an adequate radioecological knowledge base within Europe will be best maintained and the specific resources/infrastructure and skills needed to achieve this. It will also need to address the identified requirements for knowledge transfer and training within radioecology taking into account opportunities for funding training/knowledge transfer under both the EC Marie Curie Action and Erasmus Mundus Programme, and the ongoing EC funded ENEN-II project[7].

[7]See http://www.futurae.org/images/stories/Madrid2007/Radioecology-master%20info%20borchure%20-final.pdf for details of radioecology masters course support by ENEN-II.

Table 4.1. Selected information on resources, outputs and infrastructure of European radioecological research groups, as specified in either the original, or where available revised, inputs into the questionnaire.

Staff	Refereed publications per member of staff over 5 years	Facilities to conduct controlled studies of:				Accredited radioanalytical laboratory (Y/N)	Budget >€500k per year (Y/N)
		transfer to terrestrial organisms	transfer to aquatic organisms	effects of radiation on terrestrial organisms	effects of radiation on aquatic organisms		
36	***1.5***	Y	N	Y	N	Y	>€500k
35	***5.9***	Y	Y	Y	Y	Y	>€5000k
30	***2.7***	N	N	Y	Y	Y	>€1000k
30	1.3	Y	Y	N	N	N	N
28	***0.8***	N	N	N	N	N	>€500k
22	***0.2***	N	N	N	N	N	N
21	***0***	Y	Y	N	N	N	N
14	***1.6***	N	N	N	N	N	N
14	***0.1***	Y	N	Y	N	N	N
13	***4.9***	Y	N	Y	N	Y	>€1000k
12	1.3	N	N	N	N	N	N
11	1.9	N	N	N	N	Y	N
11	***0.3***	N	N	N	N	N	N
10	***4.2***	N	N	N	N	N	N
10	1.1	N	N	N	N	Y	N
8	***5.3***	N	N	N	N	Y	>€500k
8	***2.1***	Y	N	N	N	N	N
7	***7.0***	Y	N	N	N	N	>€500k
7	2.1	N	N	N	N	Y	N
7	1.0	Y	Y	Y	Y	N	N
6	***6.3***	Y	Y	Y	Y	Y	N
6	***3.0***	Y	N	N	N	Y	N
6	1.8	N	N	Y	Y	N	>€500k
6	1.2	N	N	Y	Y	N	>€500k
6	***0.8***	Y	Y	N	N	N	N
5	***3.2***	Y	N	N	N	Y	N
5	***2.8***	Y	Y	Y	Y	N	N
5	***1.6***	N	N	Y	Y	N	N
4	***18.3***	Y	Y	N	N	Y	N
4	***1.5***	Y	Y	Y	Y	N	N
3	***7.3***	Y	N	Y	N	N	N
3	***5.7***	N	Y	N	Y	N	N
3	5.3	Y	Y	Y	Y	N	N
3	***1.7***	Y	Y	Y	Y	N	N
3	***0.3***	N	N	Y	N	Y	N
2	***5.0***	N	N	N	N	Y	N
2	5.0	Y	Y	N	N	N	N
2	4.0	Y	N	N	N	N	N
2	***3.5***	Y	N	N	N	N	N
2	***0.5***	N	N	N	N	N	>€1000k
1	***7.0***	N	N	N	N	N	N
1	***7.0***	N	N	N	N	N	N
1	***7.0***	N	N	N	N	N	N
1	***6.0***	N	N	N	N	N	N
1	***5.0***	N	N	N	N	N	N
1	***3.0***	Y	Y	Y	Y	Y	N

Notes: (i) Bold/italicised text for staff and publication numbers denotes inputs which were confirmed/revised during course of preparation of this deliverable; (ii) grey shading identifies meeting of criteria outlined in text above.

An overview of the status of European radioecology is presented below in the form of a **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats (SWOT) analyses of European radioecology in Table 4.2. There is a demonstrable renewed need for radioecological knowledge within Europe. Whilst there may currently be adequate specialists and facilities to meet these needs there are currently 'threats' to sustainability due to fragmentation, reduction in specialist facilities and on-going loss of key ('Chernobyl generation') experts over the next decade. Co-operation at European level will maximise added value and provide radioecological underpinning for those countries where there is significant fragmentation.

Table 4.2. SWOT analyses – radioecology in Europe

Strengths	Europe retains radioecological expertise in a wide range of disciplines in most EU member states. There remains an adequate infrastructure to conduct most radioecological studies. There is a good track record of collaboration (funded by EURATOM) between European researchers successfully contributing to addressing radiological issues.
Weaknesses	Fragmentation - more than one third of organisations conducting radioecological research have less than five radioecologists (these are predominantly universities) – loss of key staff in these institutes may lead to cessation of radioecological activities within them. Less than 50 % of organisations who responded to questionnaire presented in Deliverable 1 have a budget in excess of €100k. The number of key specialist facilities is declining. Deliverable 1 indicated that a significant proportion of radioecological funding came from the respondents own organisation – this proportion of their budget was that which respondents were least positive about increasing/being maintained in the future.
Opportunities	Renewed need for radioecology. Europe faces many common radioecological questions driven by the need to: ➢ resolve legacy issues including the construction of waste repositories ➢ assess the contribution of nuclear power to future energy supplies ➢ respond to changing international recommendations (e.g. environmental protection) ➢ maintain emergency preparedness (including for malevolent acts). Radioecological contributions to these issues have been clearly identified in section 3 above. Europe maintains the highest competence in radioecology and there is the potential to 'export' this expertise to help address issues world-wide.
Threats	European radioecology has previously benefited greatly from the funding of co-ordinated programmes by EURATOM. A lack of European co-ordination in the future would lead to: ➢ further fragmentation of research ➢ potential complete loss of expertise in some countries ➢ further loss of specialist facilities ➢ duplication of effort ➢ loss of added value ➢ lower cost effectiveness. The average age of European radioecologists is increasing with many key scientists likely to retire within the next 10 years. There is a need, identified in a number of fora, to ensure knowledge transfer and motivate young scientists into the field.

References

ACIA, 2004. Impacts of a Warming Arctic. Arctic Climate Impact Assessment. Cambridge University Press, Cambridge, United Kingdom, 139 pp.

AMAP, 2003. AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to,Within, and from the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway,65 pp.

AREVA-EDF. 2007. UK-EPR. Fundamental safety overview. Volume 3: Environmental impact. Chapter E: Summary of environmental and health effects. Available from: http://www.epr-reactor.co.uk/scripts/ssmod/publigen/content/templates/show.asp?P=139&L=EN&SYNC=Y.

Avila, R., Beresford, N.A., Agüero A., Broed, R., Brown, J., Iospje, M., Robles, B., Suañez, A. 2004. Study of the uncertainty in estimation of the exposure of non-human biota to ionizing radiation. Journal of Radiological Protection 24, A105–A122.

Baker, A.C., Darwin, C.J., Jefferies, N.L., Towler, P.A.,Wade, D.L. 2000. Best practice guidance for site characterisation. managing contaminated land on nuclear-licensed and defence sites. A report from the SAFEGROUNDS Learning Network. CIRIA, London. Available from http://safegrounds.com.

Beresford, N.A., Mayes, R.W., Cooke, A.I., Barnett, C.L., Howard, B.J., Lamb C.S., Naylor G.P.L. 2000. The importance of source dependent bioavailability in determining the transfer of ingested radionuclides to ruminant derived food products. Environmental Science and Technology, 34, 4455-4462.

Beresford, N.A, Wright, S. M., Howard, B. J., Crout, N. M. J., Arkhipov, A., Voigt, G. 2002. Aspects of the incorporation of spatial data into radioecological and restoration analysis. In: Radiation legacy of the 20th century: Environmental restoration. IAEA- TECDOC-1280. International Atomic Energy Agency, Vienna. 425-436.

Beresford, N.A. 2006. Land contaminated by radioactive materials. Soil Use and Management 21, 468-474.

Beresford, N.A., Barnett, C.L., Howard, B.J., Rantavaara , A., Rissanen, K., Reales, N., Gallay, F., Papachristodoulou, C., Ioannides, K., Nisbet, A.F., Brown, J. Hesketh, N., Hammond, D., Oatway, W., Oughton, D., Bay, I., Smith, J.T. 2006. Compendium of countermeasures for the management of food production systems, drinking waters and forests. EURANOS (CAT1)-TN(06)-04 Deliverable D6C1R1. CEH Lancaster. Available from http://www.strategy-ec.org.uk/EURANOS_D6C1R1/index.htm.

Beresford, N.A., Mayes, R.W., Barnett, C.L., Howard, B.J. 2007a. The transfer of radiocaesium to ewes through a breeding cycle – an illustration of the pitfalls of the transfer coefficient. Journal of Environmental Radioactivity 98, 24-35.

Beresford, N.A., Anderson P., Beaugelin-Seiller, K., Brown J., Copplestone D., Hosseini, A., Howard B. J. 2007b. Approaches to demonstrate protection of the environment from ionising radiation. 27th-29th June 2007, Vienna, Austria. Workshop report for the PROTECT project. EC contract number036425 (FI6R). Available from: www.ceh.ac.uk/protect.

Beresford, N.A., Brown, J., Copplestone, D., Garnier-Laplace, J., Howard, B. Larsson, C-M., Oughton, D., Pröhl, G., Zinger, I. 2007c. D-ERICA: An Integrated approach to the assessment and management of environmental risks from ionising radiation. Deliverable of the ERICA project. EC contract number FI6R-CT-2004-508847. SSI, Stockholm.

Beresford, N.A., Balonov, M., Beaugelin-Seiller, K., Brown, J., Copplestone, D., Hingston, J.L., Horyna, J., Hosseini, A., Howard, B.J., Kamboj, S., Nedveckaite, T., Olyslaegers, G., Sazykina, T., Vives i Batlle, J., Yankovich, T.L., Yu. C. In press. An international comparison of models and approaches for the estimation of the radiological exposure of non-human biota. Applied Radiation and Isotopes.

Brown, J., Mortimer, K., Andersson, K., Duranova, T., Mrskova, A., Hänninen, R., Ikäheimonen, T., Kirchner, G., Bertsch, V., Gallay, F., Reales, N., Hammond, D., Kwakman, P. 2007. Generic handbook for assisting in the management of contaminated inhabited areas in europe following a radiological emergency. Report number (CAT1)-TN(07)-02 for the EURANOS project. EC contract number FI6R-CT-2004-508843. Health Protection Agency, Didcot.

Copplestone, D., Hingston, J., Real, A. in-press. The Development and purpose of the FREDERICA radiation effects database. Journal of Environmental radioactivity.

Copplestone, D., Bielby, S., Jones, S.R., Patton, D., Daniel, P., Gize, I. 2001. Impact assessment of ionising radiation on wildlife. Environment Agency R&D Publication 128. ISBN: 1 85705590 X. Environment Agency, Bristol.

Copplestone, D., Wood, M.D., Bielby, S., Jones, S.R., Vives, J., Beresford, N.A., 2003. Habitat regulations for Stage 3 assessments: radioactive substances authorisations. R&D Technical Report P3-101/SP1a. Environment Agency, Bristol.

Cox, G., Beresford, N.A., Alvarez, B., Oughton, D., Kis, Z., Eged, K., Thørring, H., Hunt, J., Wright, S., Barnett, C.L., Gil, J., Howard, B.J., Crout, N.M.J. 2005. Identifying optimal agricultural countermeasure strategies for a hypothetical contamination scenario using the STRATEGY model. Journal of Environmental Radioactivity 83, 383-397.

Environment Agency (EA). 1999. Technical support materials for the regulation of radioactively contaminated land. R&D Technical Report P307. Environment Agency, Bristol.

European Commission (EC). 1996. EU Directive 96/29 Euratom of the Council of May 13, 1996 laying down the basic safety standards for the protection of health of workers and the general public against dangers arising from ionising radiation. Official Journal of the European Communities, 39, L159/1–L159/29, (29.06.96).

Ferguson, C.D., Kazi, T., Perera, J. 2003. Commercial radioactive sources: Surveying the security risks. Occasional Paper No. 11. Center for Nonproliferation Studies, Monterey.

Garnier-Laplace, J., Della-Vedova, C., Gilbin, R., Copplestone, D., Hingston, J., Ciffroy, P., 2006. First derivation of predicted-no-effect values for freshwater and terrestrial ecosystems exposed to radioactive substances. Environmental Science & Technology 40, 6498-6505.

Gillett, A.G., Crout, N.M.J., Absalom, S.M., Wright, S.M., Young, S.D., Howard, B.J., Barnett, C.L., McGrath, S.P., Beresford, N. A, Voigt, G. 2001. Temporal and spatial prediction of radiocaesium transfer to food products. Radiation Environment Biophysics, 40, 227-235.

Grigoriev, I., 2004, Review of the situation at Andreeva Bay and Grehmika: Volume of waste and general plan for waste handling and facilities remediation, Contact Expert Group Report. Available from: www.iaea.org/OurWork/ST/NE/NEFW/CEG/documents /ws052004_Grigoriev-final-eng.pdf.

Higley, K.A., Domotor, S.L, Antonio, E.J., Kocher, D.C., 2003. Derivation of a screening methodology for evaluating radiation dose to aquatic and terrestrial biota. Journal of Environmental Radioactivity 66, 41–59.

Hingston, J.L., Copplestone, D., Beresford N.A., Howard, B.J. (Eds.) 2007. A review of approaches to protection of the environment from chemicals and ionising radiation: Requirements and recommendations for a common framework. Deliverable 3 of the PROTECT project (Contract number 036425 (FI6R). Available from: www.ceh.ac.uk/protect

Howard, B.J., Strand, P., Assimakopoulos, P., Bréchignac, F., Gascó, C., Métivier, H., Moberg, L., Smith, J.T., Tamponnet, C., Trueba, C, Voigt, G., Wright, S. 2002. Estimation of radioecological sensitivity. Radioprotection – colloques 37, 1167-1173.

International Atomic Energy Agency (IAEA). 1994. Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. Technical Report No. 364. International Atomic Energy Agency, Vienna.

International Atomic Energy Agency (IAEA). 2000. Restorations of environments with radioactive residues. International Atomic Energy Agency, Vienna.

International Atomic Energy Agency (IAEA). 2002. Radiation legacy of the 20th century: Environmental restoration. IAEA-TECDOC-1280. International Atomic Energy Agency, Vienna.

International Atomic Energy Agency (IAEA). 2003b. Findings of the president of the conference. International conference on security of radioactive sources. International Atomic Energy Agency, Vienna. Available from: http://www.iaea.org/NewsCenter/Features/RadSources/PDF/findings.pdf.

International Atomic Energy Agency (IAEA) 2004. Code of conduct on the safety and security of radioactive sources. International Atomic Energy Agency, Vienna. Available from: http://www-pub.iaea.org/MTCD/publications/PDF/Code-2004_web.pdf.

International Atomic Energy Agency (IAEA). 2006. Assessing the need for radiation protection measures in work involving minerals and raw materials. Safety Report Series N° 49. International Atomic Energy Agency,Vienna.

International Commission on Radiological Protection. (ICRP). 2007a. Recommendations of the International Commission on Radiological Protection. Publication 103. Annals of the ICRP 37 (2-3).

International Commission on Radiological Protection. (ICRP). 2007b. Environmental protection: the concept and use of Reference Animals and Plants. Draft 4a (for consultation). Available from: http://www.icrp.org/draft_animals.asp.

IPCC, 2001. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. In: McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), Climate Change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, United Kingdom, 1005 pp.

International Union of Radioecology (IUR) 2006a. Recommendations for improving predictions of the long-term environmental behaviour of ^{14}C, ^{36}Cl, ^{99}Tc, ^{237}Np and ^{238}U. Findings of the IUR Waste and radioecology task force. Report No. 6. International Union of Radioecology, Cadarache.

International Union of Radioecology (IUR) 2006b. Radioecology in a multi pollution context. IUR Web based questionnaire results. Research, facilities and scientific priorities. Report No. 4. International Union of Radioecology, Cadarache.

International Union of Radioecology (IUR) 2006c. Radiological Protection of the Environment. IUR Web based Questionnaire Results: Research, Facilities and Scientific Priorities Report No 5. IUR: Cadarache.

Larsson C-M. in press. An overview of the ERICA Integrated Approach to the assessment and management of environmental risks from ionising contaminants. Journal of Environmental Radioactivity.

Moberg, L., Zinger, I., Howard, B.J., Beresford, N.A., Vandenhove, H., Gariel, J-C. 2007. A study of stakeholders views on radioecological needs in Europe in the next 5-10 years. Deliverable 2 of the FUTURAE project (EC contract number FP6-036453). Institute for Radiological Protection and Nuclear Safety, Cadarache.

NIREX, 2005. Summary Note for CoRWM on the Impact of Rising Sea Levels on Coastal Sites with Radioactive Waste Store. September 2005. Report number 48438. 39 pp.

Nisbet, A.F., Howard, B.J., Beresford, N.A. & Voigt, G. 2005. Stakeholder Involvement in post-accident management. Journal of Environmental Radioactivity, 83.

Nisbet, A.F., Rice, H. (eds.). 2006. Generic handbook for assisting in the management of contaminated food production systems in Europe following a radiological emergency. Report number (CAT1)-TN(06)-06 for the EURANOS project. EC contract number FI6R-CT-2004-508843. Health Protection Agency, Didcot.

Papastefanou, C. 2006. Radioactive nuclides as tracers of environmental processes. Journal of Radioanalytical and Nuclear Chemistry, 267, 315-320.

Salbu B. 2007. Speciation of radionuclides – analytical challenges within environmental impact and risk assessments. Journal of Environmental Radioactivity, 96, 47-53.

Sohier, A., Hardeman, F. 2006. Radiological dispersion devices: are we prepared? Journal of Environmental Radioactivity 85, 171-181.

Strand, P., Balonov, M., Travnikova, I., Hove, K., Skuterud, L., Ratnikov, A., Prister, B., Howard, B.J. 1999. Fluxes of radiocaesium in selected rural study sites in Russia and Ukraine. Science of the Total Environment 231, 159-171

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 2000. Sources and effects of ionizing radiation, Publication No. E.00.IX.3. United Nations, New York.

Vandenhove H., Van Hees, M. 2004. Phytoextraction for clean-up of low-level uranium contaminated soil evaluated. Journal of Environmental Radioactivity 72, 41-45.

Vandenhove, H. 2000. European sites contaminated by residues from the ore extracting and processing industries. In: Restorations of environments with radioactive residues. International Atomic Energy Agency, Vienna. pp 61-89.

Vandenhove, V., Olyslaegers, G., Carlé, B., Howard, B.J., Beresford, N.A., Agüero, A., Gasco, C., Gariel, J-C., Garnier-Laplace, J., Ikaheimonen, T., Moberg, L., Liland, A., Smodis, B. 2007a. Assessment of the present situation of research in radioecology in Europe. Deliverable 1 of the FUTURAE project (EC contract number FP6-036453). Institute for Radiological Protection and Nuclear Safety, Cadarache.

Vandenhove H., Van Hees, M., Wannijn, J., Wouters K., Wang L. 2007b. Can we predict uranium bioavailability based on soil parameters? Part 2: Soil solution uranium concentration is not a good bioavailability index. Environmental Pollution, 145, 577-586.

Vandenhove, H., Sanzharova, N., Shubina, O., Reed, E., Shang, Z., Velasco H., Olyslaegers, G. (submitted a). Proposal for new best estimates of the soil-to-plant transfer factor of U, Th, Ra, Pb and Po. Journal of Environmental Radioactivity.

Vandenhove, H., Gil-García, C., Rigol, A., Vidal, M., (submitted b) New best estimates for radionuclide solid-liquid distribution coefficients in soils. Part 2. Naturally occurring radionuclides. Journal of Environmental Radioactivity.

Wright, S.M., Crout, N.M.J., Beresford, N.A., Sanchez, A., Kanyár, B. 2002. The identification of areas vulnerable to radiocaesium deposition in Hungary. Radioprotection - colloques 37, 1175-1180.

Appendix A: Minutes of the Workpackages 3 and 4 workshop (11-12th December 2007; Ciemat, Madrid)

Agenda

Tuesday 11th December 2007 (14:00-18:00)	
Welcome	Jean-Christophe Gariel
Meeting objectives	Brenda Howard
Presentation of WP1 deliverable (*Assessment of the present situation of research in radioecology in Europe*)	Hildegarde Vandenhove
Presentation of WP2 deliverable *(A study of stakeholders views on radioecological needs in Europe in the next 5-10 years)*	Irene Zinger
Presentation of WP 3 deliverable (*Rationalising radioecological capacity with requirements*)	Nick Beresford
Open discussion of Deliverable 3	Chair: Brenda Howard
Recommendations of the IAEA EMRAS working groups	Gordon Linsley
Wednesday 12th December (09:00-16:30)	
The need for education in nuclear areas (EURAC & ENEN-II)	Lindis Skipperud
Radioecological requirements for contaminated land issues	Peter Booth
Radioecological needs of the proposed revisions to the IAEA Basic Safety Standard	Vladimir Berkowski
Breakout group discussions of Deliverable 3 *Identification of priorities and their justification (in European context)*	
Plenary feedback from breakout sessions	Chair: Brenda Howard
Networks and other instruments for Radioecology within EURATOM FP7	Jean-Christophe Gariel
Experiences of a EURATOM Network of Excellence: ACTINET	Pascal Chaix
An industry perspective to multinational collaboration: experiences of BIOPROTA	Elisabeth LeClerc
The NKS radioecology programme	Sigurdur Palsson
Benefits of European collaboration – a regulators perspective	David Copplestone
A Network of Excellence or other instruments for Radioecology in Europe – open discussion	Chair: Jean-Christophe Gariel
Close of workshop and departure of EUG members	Jean-Christophe Gariel

NB: Most presentations are available from: http://www.futurae.org/

A.1. Workshop purpose and format

The primary objective of the workshop was to discuss the draft of Deliverable 3 (*Rationalising radioecological capacity with requirements*) which had been provided to all attendees on 29th November 2007. In addition the scope of the workshop was extended from that originally envisaged to also begin discussions of Workpackage 4 with the end user group (EUG).

To facilitate these objectives, in addition to the existing FUTURAE EUG a number of additional people from outside of the FUTURAE consortium were invited to attend and in some cases make presentations at the workshop. These included representatives of groups able to input further to identifying future radioecological requirements in the European context and also those with experience of relevant networks. In total 15 consortium and 20 end user group members attended the workshop (Table A.1).

Open discussion sessions were held to discuss the Draft Deliverable 3 and the potential for a radioecology Network of Excellence within FP7. There was also a breakout session, during which the participants divided into four groups to discuss the following questions posed by the FUTURAE consortium:

Has FUTURAE identified the areas to justify co-ordinated radioecology in Europe:

- *waste;*
- *legacy issues;*
- *nuclear power generation;*
- *protection of the environment;*
- *NORM;*
- *emergency preparedness;*

and the key issues within these?

If not what is missing and/or what is not wanted?

The views of each group were reported back to the plenary session by an EUG representative.

The following sections record these discussions although it should be noted that they do not necessarily reflect the views of members of the FUTURAE consortium (no attempt has been made to comment on (or 'correct') the discussions during the preparation of these minutes).

Table A.1. FUTURAE Madrid workshop participants.

Consortium	
Tarja Ikäheimonen	STUK
Pia Vesterbacka	STUK
Brenda Howard	CEH
Nick Beresford	CEH
Jacqueline Garnier-Laplace	IRSN
Jean-Christophe Gariel	IRSN
Irene Zinger	IRSN
Mark Dowdall	NRPA
Hildegarde Vandenhove	SCK•CEN
Benny Carlé	SCK•CEN
Borut Smodis	Jozef Stefan Inst.
Catalina Gascó Leonarte	CIEMAT
Cristina Trueba	CIEMAT
Hans Reynders	University of Antwerp
Ronny Blust	University of Antwerp
End User Group	
Philippe Ciffroy	EdF (France)
Christine Wildrot	BfS (Germany)
David Copplestone	EA (UK)
Ivica Prlic	IMI Zagreb (Croatia)
Tom Hinton	University of Georgia (USA)
Gerhard Pröhl	GSF-Research Centre for Environment & Health Germany)
Pascal Chaix	CEA (France)
Elisabeth LeClerc	ANDRA (France)
Sigurdur Palsson	Icelandic Radiation Protection Institute (Iceland) (representing NKS radioecology programme)
Lindis Skipperud	UMB (Norway)
Miquel Vidal	University Barcelona (Spain)
Gordon Linsley	IAEA EMRAS programme Chair
Peter Booth	Nexia Solutions (UK)
Vladimir Berkowski	IAEA
Ulrik Kautsky	SKB (Sweden)
Rudie Heling	NRG (Netherlands)
Francois Brechignac	IUR
Carlo Papucci	ENEA (Italy)
Marie-Odile Galler	IRSN (France)
Frederique Eyrolle	IRSN (France)

A.2 Open discussion of Deliverable 3

The following comments were made by EUG members subsequent to the presentation of the Deliverable 3 draft:

- There is a need to maintain radioecological expertise to cope with developments in (for instance) legislation and to maintain emergency preparedness capabilities.
- The deliverable should explore long-term rehabilitation requirements.
- Knowledge transfer requirements and needs to attract young scientists should be highlighted.
- Prioritise requirements.
- Do not separate radioecology and radiation protection.
- There is a need for specialists (e.g. hydrologists) to have some radioecological expertise rather than 'pure radioecologists'. Embed radioecologists within 'ecological organisations'.
- Conversely, the opinion that there is a role for generalist radioecologists was also expressed.
- Infrastructure issues should be given more discussion – e.g. unique or scarce facilities.
- Does radioecology include urban behaviour of radionuclides? If not who considers this?
- There needs to be better communication between radioecological community and other environmental issues. Also consider what radioecology can give to other fields.
- The justification needs to be linked to knowledge gaps.

A.3 Breakout group discussions

It is acknowledged that due to discussions following various presentations, prior to the breakout sessions, and time constraints thereafter the time allowable for group discussions was unfortunately limited (to 30 minutes).

Group 1

There was general consensus in the group as to avoiding the replication of EURANOS work through the emergency preparedness efforts as listed in FUTURAE.

A limited number of participants (minority) were worried about whether "radiological" preparedness should be separate from "normal" emergency preparedness. The question was posed by these participants as to whether "response" is included in the concept "preparedness".

Multipollutants were discussed with consideration of whether this could be harmful for EURATOM funding. At the same time, multipollutants should be an important topic for the network.

The group members also wanted 1) waste issues and 2) marine pollution included. The latter topic was only mentioned by one member but this member was insistent.

There was a discussion as to whether security was relevant to radioecology. Example discussed from Croatia but no agreement aside from it being an issue of semantics.

It was also suggested that consideration of the use of radioactive tracer to understand basic ecological processes should be included within D3.

Overall consensus: general agreement with the categories, D3 addresses most important topics but could be better structured as there was felt to be overlap.

Group 2

There was discussion of training – this is cross-cutting but should it be an additional activity in its own right? One member of the group stated that training could not be used as a justification for a NoE, as there are other funding instruments available (Erasmus Mundus). Although it was also noted that education can be driven by scientific research collaboration.

The question was asked – is behaviour in urban environments radioecology and if not where should it be considered? Some members of the group agreed that this is radioecology if considered as a whole ecological system.

It was stated that the presentation on the IAEA Basic Safety Standards demonstrated a lack of understanding on 'how to protect the environment' demonstrating the need for research.

One member of the group felt that remediation was not well covered within D3 (legacy issues), whilst it is lead by engineering it requires radioecological knowledge to optimise strategies.

It was suggested that nothing was missing from D3 but that there was a need to bring-out the cross-linking between themes (e.g. environmental protection crosses them all) and a need to focus research. It was suggested that requirements could be justified on the basis of uncertainties identified within previous assessments which may better demonstrate why issues are important, i.e. do not just identify data gaps but show where they become important within an assessment.

It was stated by one group member that parts of the deliverable read like a 'wish list' and that consideration of waste was rather short compared to that for NORM. One suggestion to address this was to reduce/restructure the NORM sections.

One group member expressed the opinion that radioecology roles in waste issues may be limited, for instance how could transfer factors be scaled over 1000's of years into the future.

One group member stated that D3 did not considered three large waste related projects[8].

It was suggested that further EURATOM projects could be referred to improve the justification within D3.

It was suggested that there is a need to maintain radioecological competence for current activities. If this disappears then trust in the whole assessment is undermined. However, the opinion was also expressed that some states would maintain this level of competence because they have to and that D3 should stress the European level.

Some members of the group felt that further discussion was difficult without fully understanding the aims of NoE's.

[8] The EUG member subsequently supplied the websites for these: www.nf-pro.org; www.funmig.com; www.ip-pamina.eu.

Group 3

Comments on the six suggested themes

In general it was agreed that the 6 themes were important and no theme should be removed from the list.

It was suggested that a NoE was important for harmonization of strategies

It was suggested that we could/should show that radioecology could be useful to other environmental fields: e.g. the use of tracers is important for studying and unravelling environmental processes (e.g. sedimentation, transfers which are common to all stressors; tool for validating models. The use of tracers can be applied in virtually all 6 domains.

It was also suggested that mixed stressor situations cut across the various themes.

Societal aspects/pressure are/is important in justification of need of radioecology. Although societal pressure is less important for routine releases but it may be important in waste disposal, emergency preparedness.

Radioecology is needed to demonstrate that the environment is protected. All nuclear activities have to be screened to ensure that the environment is protected

Use radioecology to demonstrate remediation actions are efficient both for legacy sites and NORM sites

Put the six areas into a European context, for instance, for waste you have to identify subtopics and identify what is required in a European context (e.g. NORM waste: is behaviour of NORM different in original state or after processing).

We should demonstrate WHY the current state of art is not sufficient to answer three following points for each of the 6 domain only then can we justify need for NoE:

- Why is it needed for society
- Why is radioecology needed for industry
- Why do we need European scale network
- What is benefit of an NoE?
- Will knowledge be better exchanged and used by an NoE

A NoE will lead to a better harmonization and make management across boundaries possible. It should contribute to more uniform assessments; harmonisation of parameters; trust building.

Comments on D3

General suggestion on inclusion of following in D3:

- Socio-economic motivation to do the six activities listed
- What is added value of a NoE?

Imbalance between items at presence in text: waste repositories few lines and NORM 1.5 pages. Currently in waste only behaviour is discussed but effects should also be introduced.

Examples are given for animal food chain TF and nothing on availability, on soil to plant TF on effects; if you give these examples then it seems as if this is the most important issue and it may not be. Should be rectified and balanced.

D3 looks like a wishing list should be more focussed.

Many subjects are example driven and not objective driven.

Legal differences between countries: In France only dose to man in (e.g.) Norway also dose to environment. This may influence needs for different countries and should be mentioned in D3.

Group 4

In the open discussion of D3 legislation had been mentioned as an issue. Nobody in the group could identify specific issues in that area.

Decision: incorporate legislation within each theme.

Themes are currently described as scientific issues, areas of expertise. Perhaps an NoE should be more directed at *sharing existing capacities*, e.g. scarce facilities such as a ship. One suggestion to address this was to introduce this in SWOT analysis. One of the problems is that the WP1 answers to the questionnaires do not tackle this. A good example – not shown in questionnaire – two centres (UK and Norway) have the expertise for large mammal experiments but no facility and one centre (Belgium) has facility but no expertise in that area.

Need to fill in the gaps in the WP1 questionnaire in terms of infrastructure. One solution is to get people's knowledge on identifying unique European facilities to enable NoE to work better.

In the questionnaire responses, all institutions have said they can do low-level measurements for alpha, beta and gamma. It is not clear whether they have accreditation to do these. It was suggested that it was important to determine who can do very-low level radioactivity measurements (metrology in French).

Decision: follow-up WP1 questionnaire results.

Fragmentation was shown by WP1. The real numbers may be 400 to 500 radioecologists. We should not be too concerned for NoE about the total number of radioecologists as it requires the 'big players'. But you also need to identify people who do good research (via peer review papers). So both approaches (resources and outputs) are need.

Decision: ask participants to identify who are IUR members – may give an idea of total numbers of radioecologists by extrapolation.

Following presentation by this group to the plenary meeting participants were asked if they were IUR members. Approximately 50 % were, which is in broad agreement with the ratio between the number of IUR members in European Union member states and the total number of radioecologists suggested in D3.The opinion was expressed that given the objective of FUTURAE it was not surprising that there was 'over reporting' of staff numbers etc. and a positive view of the future (i.e. respondents were likely to have seen responding in such a manner as more likely to lead to future funding/their involvement in any NoE).

Although marine ecosystems may not be especially radioecologically sensitive they are extensive and early effects of climate change may be identified through the use of tracers for marine currents and drifts.

Climate change is important and has a big effect in the marine environment. It should be mentioned within the relevant themes (at least three themes identified) at both short and long-time scales. Teaching is also relevant and should be tackled for each of the themes and included in the discussion.

Decision: mention climate change and teaching in WP3 report.

Following presentation of the group discussions in plenary it was noted that FUTURAE would attempt to address the comments where possible. However, some of the discussion points were more applicable to Workpackage 4 and would be retained for consideration in that phase of the project.

A.4 Open discussion: A network of excellence for radioecology in Europe?

This discussion followed various presentations on existing networks including the ACTINET NoE and feedback from the FUTURAE co-ordinator on a meeting between the EC-IRSN-CEH to discuss a NoE for radioecology in FP7. It was stated that the proposal was for one NoE and that other funding instruments were not being considered. There needs to be demonstration of durable integration after the end of NoE. It was felt that the NoE would have approximately 4-5 core institutes and a total of 10-12 members. The budget would be in the region of €3-5 M over 3-5 years.

The question was asked of participants - is a NoE required and/or useful for radioecology in Europe?

One EUG member noted that, there are clear needs for co-ordinated action at the level of research requirements and that a NoE offers the opportunity to take forward. What they had not realised is that an NoE would be focussed on academic community and was therefore worried about how end-user needs would be met. Would be glad to see this addressed in D4.

The member was asked if they would be happy to see the advisory board made-up of end-users?

The response was 'yes – we are at the sharp end and need focus'.

The FUTURAE co-ordinator noted that an NoE is not co-ordination but collaboration.

An EUG member stated that 'Seems like a logical [if forced] evolution of our science. Logical as each of our individual programmes collapse that we combine forces. But do keep to just Europe, obviously EC is not going to fund – but this is early enough that other countries can gain the funding'.

It was stated that the EC encouraged such wider collaboration, in WP4 approach some people to see if there is that buy-in. Other NoE have established collaboration outside of Europe.

An EUG member stated that they were in support, but asked 'What does it mean for a minor player to be in a NoE. What are the practical implications for smaller groups.'

It was suggested that this was somewhat as a paradox as FUTURAE was suggesting fragmentation of radioecology within Europe but a NoE would concentrate on a core group of 10-12 larger groups.

FUTURAE members stated that they had the strong impression from the EC that ACTINET was considered to be too big. However, we do not know the flexibility to involve minor players.

An EUG member suggested that if endusers are involved they may be able to contribute funds to support additional participation.

The IAEA representative suggested there were clear potential connections between NoE and statutory functions of IAEA. The IAEA would appreciate formal and informal contacts. IAEA has lack of knowledge of who is who in radioecology. IAEA has programme on training – managers have problems identifying appropriate people. Co-ordination between NoE and IAEA be really valuable in all aspects. Consider your activity not just in EC aspect but much broader.

It was noted by the FUTURAE co-ordinator that there were contractual problems with the IAEA. Although it was suggested that the IAEA could register an intent to participate within the advisory committee of an NoE.

An EUG member suggested that the problem was to convince the Commission not the wider radioecological community. However, it was suggested (by a FUTURAE participant) that the main concern of the EC is will the radioecological community buy in and if there is support of endusers, IAEA, industry etc. that is better. The most important support is that of senior management within potential network participants.

The IUR representative suggested that the 'IUR is already a network – mistake and difficult to Commission if ignore this. Encourage appropriate linkage – not partnerships to optimise'.

It was pointed out that D3 mentions the IUR, and the IUR may participate within an NoE as suggested for the IAEA.

An EUG member expressed the opinion there was a 'problem with exclusive teams and that the process of selection would be difficult' Suggesting that the Commission should be approached to determine if a larger NoE was possible.

In response it was suggested that FUTURAE should do this but also explore opportunities to be more inclusive.

An EUG member asked if the limit (on participants) being suggested was financially driven.

In response it was reiterated that the level of funding was €20k/researcher/year with an anticipated budget of €3-5M so the sums are fairly easy to do.

There was discussion over the suggested number of NoE members with some EUG members expressing the opinion that it was too restrictive and that groups would feel 'excluded'. Conversely it was argued (by a consortium member) that a large NoE would fail.

An EUG member asked how would participants be determined.

The FUTURAE coordinator pointed out that at the end of FUTURAE all partners would not have to be identified just a core group of organisations with the management commitment to enable an NoE. We are not at the stage of a call – but convincing the EC that a NoE is required and viable.

An EUG member stated: 'Radioecology has become a small area. So a NoE is necessary for success in the future. In many countries we are now below critical mass – if drop below this we will fail. We are forced to follow this direction as the only option. But have to live with that - it is a good opportunity – good consortium to address the priority gaps. Principle is OK – it is the only possibility. It is a good possibility to get successful work. We are experienced; know each other, our weaknesses and strengths.'

Another EUG member stated: 'The EC is presenting – accept this or do not. How is the larger radioecological community going to accept the small group.'

In response it was suggested that 'We only have to have the key players signed up. The Commissions main concern is buy-in of key players – infrastructure, durability'.

The FUTURAE co-ordinator stated that he would go to the Commission to address questions being asked.

There was discussion over the (i) potential to increase the NoE as time went on and if justified; (ii) mechanisms of involving the wider community (including access to facilities, funding to attend workshops, dissemination of knowledge, fellowships) and avoid having an 'exclusive club'. One EUG member express the opinion: 'Great opportunity after 18 months can do what you want – how often do you get the opportunity to do that?'

It was suggested that NATO may provide funding for small players tagged onto larger network.

The FUTURAE co-ordinator stated he would go back to the Commission on numbers/constraints/mechanism of involvement for people out with the NoE/potential increase with time.

It was asked if EC funding would continue beyond 5 years – the response was no.

An EUG member suggested that: 'Worst case scenario – this is last chance of multi-national funding. So need to bring in regulators/industry early.' It was accepted that this gives importance to advisory committee and linking to BIOPROTA etc..

The was some discussion with regard to the WP1 questionnaire giving a false impression, some participants expressing the view that people saw it as an opportunity.

Summarising the discussion the FUTURAE co-ordinator suggested the view from the workshop was:

- *NoE - yes or no?* – **yes**
- *NoE of 10-12 organisation?* – **reservations and need to investigate solutions.**