BIOPROTA

Key Issues in Biosphere Aspects of Assessment of the Long-term Impact of Contaminant Releases Associated with Radioactive Waste Management

Report of the Eleventh BIOPROTA Workshop

Madrid, Spain
6-8 May 2009

Hosted by CIEMAT

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Preface

The forum and this report were produced within the international collaboration project BIOPROTA.

The report is presented as working material for information. The content may not be taken to represent the official position of the organisations involved.

Report History

Version 0.1 Draft, 4 June 2009, prepared by Enviros and GMS Abingdon for review by participants.

Version 0.2 Final, 30 June 2009, prepared by Enviros and GMS Abingdon and modified to include comments from participants.

Contents

1. INTRODUCTION

1.1 Objectives of the Eleventh BIOPROTA Workshop

The objective of the workshop was to update interested parties on progress since May 2008 on the various tasks supported through BIOPROTA and to provide a forum for continuing exchange of information and discussion about additional topics of interest. It was intended that discussions would highlight continuing areas of common interest upon which future BIOPROTA tasks could be built. The meeting therefore focused on progress to date and implementation of a future work plan.

The workshop was hosted by CIEMAT in Madrid, Spain. The support of CIEMAT in the organisation of the workshop is gratefully acknowledged.

1.2 Participation

There were 32 participants from 10 countries, representing a range of operators, regulators and technical support organisations. Participants are listed in Appendix A.

1.3 Report structure

The remainder of this report provides:

- An overview of progress made in 2008/09 (**Section 2**);
- An overview of parallel working groups (**Section 3**);
- A summary of presentations made by participants on their biosphere programmes and any challenges faced (**Section 4**);
- An overview of the forward BIOPROTA programme for 2009/10 (**Section 5**); and,
- Forum administrative issues (**Section 6**).

2. PROGRESS IN 2008/09

A number of projects have progressed since the May 2008 BIOPROTA workshop, including a second phase of the Cl-36 biosphere modelling project, modelling of Se-79 in the soil-plant system (SeSoPla), modelling of C-14 in the biosphere, a non-human biota sensitivity and knowledge quality assessment, review of approaches to site characterisation and development of a web-access portal for the BIOPROTA specialised database. An overview of each of these projects is provided below.

2.1 Chlorine-36 in the biosphere

Chlorine-36 is one of the dominant radionuclides in post-closure assessments and yet there remains a degree of uncertainty associated with the approach to modelling the behaviour of this radionuclide within the biosphere, particularly in relation to the accumulation in soil and subsequent uptake into plants. Consequently, a two phase project has been undertaken to compare the scientific basis supporting alternative approaches. Phase I focused upon modelling the contamination of soils and uptake into crops. Phase II developed the project into the assessment of dose through consideration of uptake into animals and humans.

The project has been supported financially and/or technically by the following organisations:

- ANDRA, France;
- NDA (RWMD), UK;
- EdF, France;
- JGC Corporation, Japan;
- EPRI, USA;
- IRSN, France;
- Société de Calcul Mathématique, France;
- Oregon State University, USA;
- Quintessa Limited, UK;
- Mike Thorne and Associates, UK; and,
- GMS Abingdon, UK.

Phase I (Soil Contamination and Plant Uptake)

Laura Limer (Quintessa) gave an overview of phase I of the project (soil contamination and plant uptake). The aim of phase I was to investigate alternative approaches to biosphere modelling and, on the basis of the comparison, to make recommendations on improvements for biosphere models. A report on the findings of the inter-comparison has been published by ANDRA[1].

Conventional, specific activity and complex flow and flux models have been compared and the key model assumptions are detailed below.

[1] Limer L, Albrecht A, Marang L, Miquel S, Tamponnet C, Nakai K, Gierszewski P, Thorne M and Smith G (2008). Investigation of Cl-36 Behaviour in Soils and Uptake into Crops. A report prepared within the BIOPROTA international cooperation programme and published by ANDRA: C.RO.ASTR.08.0048.

Conventional models	Specific Activity models	Complex flow and flux models
♦ Residence time and accumulation of Cl-36 in the soil rooting-zone is based on infiltration of water into deeper soil ♦ An instantaneous equilibrium soil-water distribution coefficient (Kd) is applied to determine the mobile fraction ♦ A fixed soil to plant concentration ratio (CR) is applied to determine the Cl-36 concentration in the plant as a result of root uptake ♦ Uptake into animals is calculated through the application of a transfer factor (TF)	♦ Cl-36 reaches equilibrium in some components of the system in proportion with stable chlorine ♦ Definition of which components are in equilibrium depends on a number of factors ♦ An Isotope ratio approach is used to define Cl-36 uptake by animals ♦ Some consideration is made of stable chlorine diet requirements (both animal and human)	♦ Uptake of chlorine into plant is by both passive and active processes (Michaelis-Menton) ♦ Dynamic treatment of Cl-36 movement between components ♦ Water content of compartments is time-invariant ♦ Organic chlorine included ♦ Concentration factor (CF) approach used for Cl-36 uptake by animals ♦ Some consideration is made of stable chlorine diet requirements (both animal and human)

Two source terms were considered (contaminated irrigation water and contaminated groundwater) in combination with three crop types – leafy vegetables, root crops and cereals. For the irrigation scenario, the amount and timing of irrigation events was site dependant, with both coastal and inland sites considered. For the groundwater scenario, it was assumed that the water table was two metres below the surface.

For the coastal irrigation scenario, a higher stable chlorine concentration was assumed, due to the marine influence, and this served to reduce predicted Cl-36 concentrations in plant crops. Specific activity models provided the highest Cl-36 predictions for crops inland, but predictions reduced significantly at the coastal site due to stable chlorine assumptions.

It was noted that: variation within models was similar to the variation between models; irrigation rate was the main factor affecting model predictions; and, the inclusion of cropping reduced the time required for equilibrium to be reached whereas increased sorption (Kd) delayed the time to equilibrium.

Concentrations predicted in the groundwater scenario were lower than for irrigation scenarios. In some models, no capillary rise was calculated due to maintained soil moisture conditions and therefore Cl-36 was not predicted to be taken up into crops.

Overall, conventional models were found to predict lower Cl-36 uptake into crops. However, more complex models predicted uptake within the range of values predicted by conventional models.

Phase 2 (Dose Assessment Uncertainties and Variability)

David Bytwerk (Oregon State University) presented Phase II of the project, which focused on Cl-36 dose assessment uncertainties and variability. Fewer models were actively involved in Phase II. However, additional technical support was provided by JGC Corporation and IRSN.

A single inland irrigation scenario was considered, but the assessment was extended to include fruit crops and five animal products. Doses to three age groups (infant, child and adult) were predicted.

Compared with phase I, stable chlorine concentrations were increased, resulting in a reduction in the soil isotopic ratio. Irrigation rate was also amended so that soil was no longer maintained at capacity (i.e. soil was no longer water-logged). Variant calculations were also performed. These included the irrigation of fodder and subsequent supply of contaminated product to cattle and application of alternative dose coefficients to those provided by ICRP.

Only one model (NDA-RWMD) included the formation of organic chlorine and this resulted in the model not achieving equilibrium conditions over a period of 10,000 years - alternative models achieved equilibrium within 10 to 100 years. This finding suggests that the formation of organic chlorine and its accumulation in soil organic matter may be an important area to resolve for long-term behavioural and impact assessments.

Dose to adults was calculated on the basis of diets averaged from the default assumptions across the range of models (i.e. presenting a 'consensus' approach). Predicted doses differed by around one order of magnitude and the relative behaviour of models was similar for all age groups assessed.

The main differences in model predictions arose from variation in the soil-to-plant calculations; however no source of variation was found to affect dose by more than one order of magnitude. The important pathways for uptake of Cl-36 into crops varied by type: root uptake was main pathway for cereals; irrigation and interception were the more important pathways for leafy vegetables; and, uptake into foliage and subsequent translocation to the root crop was the major pathway for root vegetables. When predicted plant concentrations were averaged across all models and fixed, adult dose calculations were more similar (around a factor of 3 difference between the model maximum and minimum predictions), indicating that the basic intake and dose coefficient approaches within each model are relatively uniform.

If it is assumed that cattle consume contaminated fodder, in addition to intake of contaminated water, there is a predicted increase in concentrations of Cl-36 within cattle products by around a factor of 5.

Phase II of the Cl-36 project has progressed well. It is intended that further work on sources of variation will be undertaken through an analysis of the effects of simultaneous variation in multiple Cl-36 specific factors, and results will be further analysed to form the basis of discussion within the draft report.

Discussion

The value of model inter-comparisons in advancing knowledge was questioned by Ulrik Kautsky (SKB). In this case, it was noted that throughout both phases of the project there has been detailed discussion between modellers, leading to continued adaptation and enhancement of the models. This has reduced the variation in model predictions based on a better understanding of pathways and processes.

Interest was also noted, during discussions, in undertaking a validation exercise: comparing model predictions to an observed set of data for an identified site. There was general agreement that a phase III should be considered if a suitable database becomes available.

The issue of extreme environments and its affect on chlorine behaviour was raised by Maryla Wasiolek. Death Valley in the USA (in the area adjacent to Yucca Mountain) is a very different environment compared with that considered during the current Cl-36 project. Most notably, groundwater in the vicinity of the proposed Yucca Mountain facility may rise to the surface at a point distant from the disposal facility. Evaporation of the water would then result in the formation of salt deposits on the surface, leading to localised accumulation of Cl-36.

2.2 Selenium-79 in the soil-plant system

Steve Sheppard (ECOMatters) gave an overview of a recent review of observational data, that has been undertaken to determine the potential scale, and effect, of volatilisation of selenium from sediments and soils, as an input to the ongoing Se-79 SeSoPla (Selenium in Soils and Plants) project.

The volatilisation of selenium is a parameter that has not been routinely included in biosphere models but may be an important loss mechanism from the system (selenium is a good chemical analogue for sulphur, for which volatile emissions from soil and plants can be readily detected from the distinctive smell). A literature review was therefore undertaken to identify potential volatilisation rates for selenium, to enable this process to be incorporated into biosphere models.

The review identified, and collated, cases where volatilisation of selenium has been recorded. However, since scientific literature is unlikely to report cases where no volatilisation was recorded, a 'typical' volatilisation rate around the 25th percentile was calculated to account for possible data bias. On this basis, a loss rate of around 3% per annum from soil is suggested (implying a half time for retention of 23 years), and for sediments the estimated rate of loss rises to around 6.5% per annum.

Analysis of the relationship between volatilisation rate and soil parameters (Kd, clay content, soil Se content) did not reveal any strong correlations; although there may be a negative correlation between volatilisation rate and increasing soil organic carbon content. It may also be the case that volatilisation rate decreases over time, although the lack of long-term data makes detailed analysis difficult.

Currently in many models, selenium concentrations would be predicted to accumulate over time. Results from this study suggest that accumulation would be much less marked and hence the significance of Se-79 in biosphere assessments would be reduced.

Experimental work on the volatilisation of selenium from soils is currently being undertaken by IRSN, who are also contributing to the SeSoPla project.

Discussion

The loss of Se-79 from soil to atmosphere could be used to imply that uptake by inhalation should be considered in models; although there is no anticipation that this would be significant, as it is anticipated that there would be rapid dispersion.

The robustness of the data upon which the volatilisation rate was calculated was queried and the degree to which the rate of volatilisation could be extrapolated over longer time periods. Steve explained that data were mainly obtained from laboratory studies, but some field studies were included. The greater rate of loss observed for short time studies may be a factor relating to experimental design, although a real decrease in the rate of loss cannot be ruled out. Extrapolation to longer time periods is difficult due to lack of data. At longer times, the rate of loss of Se-79 may be affected by the background stable selenium concentration in soils.

Whether or not isotopic dilution should be taken into account in selenium models was also questioned. Overall it was considered that this may be appropriate since stable selenium is routinely added to soils and/or animal diets so there is the real possibility of isotopic dilution. However, it was noted that Finnish research (presented during a SeSoPla project workshop) suggested that selenium added to soils is rapidly lost from the system. Steve suggested that this may be indirect evidence for volatilisation.

It was suggested that it may be useful to identify volatilisation data for sulphur, for comparison with that for selenium. Mike Thorne noted that C-14 volatilisation studies are planned by the NDA RWMD (both field and laboratory soil column experiments). It was noted that whilst field Se-79 studies would not be possible, both selenium and carbon could be investigated in parallel within laboratory studies and then results extrapolated to the field on the basis of carbon in field investigations.

2.3 Carbon-14 Model Inter-comparison

Mike Thorne (Mike Thorne & Associates) gave an overview of the ongoing C-14 model inter-comparison project. This project is being undertaken by Quintessa Limited, ANDRA, EdF and Mike Thorne and Associates (on behalf of the NDA RWMD) and is supported financially by ANDRA, EdF, NDA RWMD, NUMO and SSM. Three models have been included in the project to date – those of EdF, ANDRA and NDA-RWMD. The scenario involves the use of contaminated irrigation water and prediction of soil, crop and canopy atmosphere C-14 concentrations.

Two factors were found to drive differences in model output – canopy atmosphere transfers, both with the soil atmosphere and the free atmosphere above the canopy, and the interplay between photosynthetic uptake and plant respiration. Only a small fraction of C-14 in plants was found to derive from root uptake, even though the specific activity in soil solution was around an order of magnitude greater than that in the canopy atmosphere. A much higher soil-to-root transfer rate would be required before this became the dominant pathway for uptake into plants.

Sensitivity studies have been undertaken. In the case of canopy dilution, model predictions were all similar, but the approaches taken varied. Dilution of C-14 with stable carbon affects plant uptake such that, where the dilution factor is reduced, plant uptake is increased. The effectiveness of gas transfer across soil surface and across the canopy boundary also affects results.

Concentrations predicted from the NDA-RWMD model were greater than for other models due to the assumption of a closed canopy, which may be unduly cautious for many crops (e.g. leafy vegetables).

Discussion

In discussion it was noted that existing literature on processes can be used to improve models. In the case of C-14, the main factors of importance are the prediction of C-14 in the gas phase and subsequent modelling of the photosynthesis process to achieve uptake into, and retention within, plants.

Loss of carbon via volatilisation during spray irrigation may be an important factor affecting the retention of C-14 within a system. In the case of flood irrigation, large losses would not be expected.

2.4 Update on Iodine in Peat Bogs

Yves Thiry (ANDRA) provided a brief update on the status of the iodine in peat bogs research project, investigating the long-term retention of iodine on organic matter.

Scientific papers have been produced. The first focused on the method applied; however, this was rejected for publication. This has therefore been combined with the second paper that outlined the results and the combined paper is to be submitted to the Journal of Analytical and Applied Pyrolysis following internal review. The draft paper has been made available to sponsoring organisations.

2.5 Non-Human Biota Sensitivity and Knowledge Quality Assessment

Karen Smith (Enviros) gave an update on progress with the non-human biota (NHB) sensitivity and knowledge quality assessment project, which is being undertaken by Enviros in partnership with Facilia, and is supported financially by Posiva (Task Leader), NRPA, SKB and ANDRA.

The project aims to identify: (i) the key sensitivities in NHB assessments (using the ERICA assessment approach) in relation to long-term assessments for geological disposal facilities (i.e. those affecting dose to the greatest degree); and, (ii) those parameters for which we have least certainty in the supporting knowledge base. The overall approach is to assess:

- Which parameters results are particularly sensitive to;
- Where it is appropriate to apply analogues to bridge data gaps and which analogues are most suitable;
- Whether key uncertainties can be reduced through the application of site-specific information; and,
- Where efforts should be focused to address key information gaps.

It is also intended to identify conceptual uncertainties arising from the application of the ERICA approach to GDF assessments in order to improve interpretation of assessments.

To date, an initial sensitivity study has been completed to identify, on the basis of a unit release for each radionuclide of interest, the key parameters affecting dose (e.g. concentration factor, Kd, dose conversion coefficients, occupancy habits, dimensions of reference organisms and radiation weighting factors). A site-specific run has also been performed on the basis of predicted environmental concentrations in soils and freshwater for the Posiva site at Olkiluoto. As would be expected, concentration factor is the main parameter in most instances since this can vary by up to three orders of magnitude for any radionuclide-reference organism combination. However, for high beta-gamma emitting radionuclides, Kd was found to be an important parameter for freshwater benthic organisms.

A questionnaire has also been developed, to form the basis of the knowledge quality assessment. A series of questions is posed to gauge the opinion on the pedigree of the underlying database and on the conceptual approach, specifically in relation to GDF scenarios. The draft was presented to IUR participants prior to the BIOPROTA workshop and a number of suggestions were made to increase clarity and encourage completion (e.g. reducing the number of parameters to be scored). An amended questionnaire will be distributed before the end of May to all those who have expressed an interest in participating, including experts in NHB assessment and GDF, external to IUR and BIOPROTA.

It is intended that the results of the knowledge quality assessment will be made available, along with final sensitivity analyses run for additional cases, including SKB site environmental concentration predictions, for a project workshop in September. The date and venue for the workshop are to be confirmed.

2.6 Site Characterisation

Graham Smith (GMS Abingdon) gave an update on a review that aims to improve guidance on site biosphere characterisation requirements. The project is being undertaken by GMS Abingdon in association with Amphos 21 and is supported by NUMO and ANDRA.

An initial report on site characterisation was published in 2006 under Theme 3 of the initial BIOPROTA work programme. The report identified, at a site generic level, what should be characterised, including site topography, near-surface lithostratigraphy, water bodies etc., all in relation to the stage of GDF development. The way in which site characterisation should be conducted (i.e. the way in which data should be collected in order to support model development) was also outlined.

The intention of the 2008/09 project was to improve upon the guidance given in the 2006 publication through review of current site characterisation programmes to identify where recommendations can be improved. The intention is not to conduct a critical review of ongoing characterisations, but more to provide a note of experience.

Those involved in site characterisation programmes were consulted via a questionnaire to gain information on their experience and to gain information on what has been (or is being) measured, how measurements have been/are being conducted and how the data has/will be used. Information was also requested on appropriate spatial/temporal averaging and protocols for making measurements were requested. Information has, to date, been received from SKB, Posiva, ANDRA, NDA and NWMO.

Both SKB and Posiva were able to provide quite detailed information on the site characterisation process due to the advanced nature of their GDF programmes. This has included activities to understand the historical development of the site and studies to evaluate current and historic human communities and land use in the areas surrounding the GDF sites.

Information provided by ANDRA was focused on a more qualitative description of the biosphere, addressing primarily the palaeo-climatic evolution of the site, the trophic chains and expected evolutions. However, it was noted that the site characterisation programme is currently developing and further information may now be available.

Neither NDA nor NWMO have sites identified at present and therefore the information provided was more based upon what would be measured once a site has been identified. In the case of the NDA, one of the aims of work conducted to date has been to consider site characterisation needs as a means of identifying resource requirements – how many people would need to be deployed in order to achieve site characterisation requirements?

A general approach is to describe the present, infer the history and, from this historic starting point, develop models which are able to describe the present site conditions. Once the present can be successfully understood, the same model concepts can be extended as a means of investigating how the site could evolve in the future, based on assumptions for key driving forces such as climate change.

It is hoped that the comparison will identify those areas of commonality in site characterisation programmes (i.e. those aspects applicable to all sites). From this, more site-specific site characterisation needs (e.g. those required to delineate between different candidate sites) may be identified.

2.7 BIOPROTA Database

Thomas Hjerpe (Saanio & Riekkola) presented the web-based version of the BIOPROTA database that is under development. The intention is to make available the information gathered under previous database projects in a web-access system to which sponsors may add additional data in individual project folders.

The project is being run in two phases. Phase I (funded by Posiva, NDA-RWMD, ANDRA and SKB) aims to describe the database system and how it can be used. Phase II is to be defined following feedback from sponsors on the prototype version.

Phase I is largely complete. Documentation has been distributed to project sponsors that outlines the functionality of the database and the scientific structure has been defined and populated with around 200 data points (from previous versions of the BIOPROTA SDB). Sponsors have also been provided with login details and testing of the prototype is underway.

Access to the database can range from write-enabled access through to read-only. It is possible to implement that access can be varied so that some folders of data can be write-accessed or read-only depending on data ownership.

There is a high capacity for quality control through the appointment of a scientific committee for data control. All data history is maintained and data are associated with a usability status that ranges from 'deleted' to 'approved'. This enables draft data to be entered and users can select their preferred quality control status of data for input to assessments.

The database allows for multiple folders (tags) to be generated for project data entries. Data import/export from MS Excel is supported and attachments such as files or web-links can be added to support data selection.

Each data point is allocated dependencies, which relate to how the value should be applied (for example, Kd values may be given dependencies relating to the particular soil type to which they relate). The database is intended to be a living data source and allows easy sharing of data between organisations, with all data being stored in a common format with standard categories assigned. Folders could be developed to include electronic storage of large datasets (e.g. from TRS-364 or its successor).

The ability to multi-tag data (i.e. allow one user to select data for use where others may have rejected it) is an area requiring further development.

3. OVERVIEW OF PARALLEL WORKING GROUPS

3.1 EMRAS II Waste Disposal Working Group

Gerald Kirchner (BfS) gave an overview of the EMRAS II Waste Disposal Working Group, which was formed in January 2009 and will run for a 3 year period. The overall aim of the working group is to improve capabilities in the field of environmental radioactivity dose assessment in relation to geological disposal facilities. This will include development of:

- reference modelling approaches and reference cases for present and future biospheres, including environmental change (climate, society and land use); and,
- a set of models/cases to allow assessment of biosphere impacts for a wide range of environmental situations.

Participants at the first Working Group meeting varied greatly in their level of experience and this led to differences in the types of approach favoured for the group (e.g. whether generic or site-specific); however there was consensus on other areas, in particular simulating the consequences of environmental changes as driven by climate change.

The GBIZ (geosphere-biosphere interface zone) was also discussed and was considered to be an aspect of particular importance for the group. The GBIZ concept encompasses those processes within the biosphere that influence the geosphere and *vice versa*, and the following were selected for further consideration by the working group:

- soils in areas with a low ground water table;
- sediments of freshwater bodies or the sea;
- freshwater bodies or the sea; and,
- withdrawal of contaminated water from a well.

Additional discussions focused on:

- Potentially relevant processes relating to environmental transport and exposure to man (the output of which very much resembled a FEP list);
- Long-term processes that may modify the behaviour of radionuclides in environment such as climate (e.g. its influence on geochemistry) and long-term soil development (typically a slow process, but relevant to long-term assessments, and itself affected by climate); and,
- Erosion, which is a problem in many parts of world and typical erosion rates suggest that this may be an important process for consideration; however the consequences for long-term assessments are difficult to address.

A tentative work plan has been developed on the basis of discussions:

- Participants will aim to identify the impact of climate on processes relevant to dose assessments (on soils, lakes, and landscapes as a whole). Once impacts have been identified they will be discussed to identify which processes are generic and which may be specific for particular sites, climates and/or countries. Modelling approaches will also be considered to identify which processes have been taken into account and what modifications may be needed to ensure all important processes are included.
- For GBIZ studies, the initial focus will be on present-day temperate climates and the influence of changing climate situations will then be explored in order to identify

where modifications to assumptions, models, processes and parameters may be required.

The focus of the group will be on the radionuclides Cl-36, Ni-59, Se-79, Tc-99, I-129, Ra-226, Np-237 and Pu-239.

It was noted that there is a large overlap between participants in the Working Group and those of BIOPROTA and there is a desire to ensure that work is complementary between the two groups, to avoid duplication. Additional participants to the group are invited, as are proposals for analyses that would complement the studies outlined.

Continued interaction between the working group and BIOPROTA will be achieved through the BIOPROTA Chair and the Technical Secretariat.

3.2 IUR Radioecology and Waste Task Force

The current status of the IUR Radioecology and Waste Task Force Working Group was presented by Almudena Agüero (CIEMAT). The main objective of the working group was to promote cooperation between radioecologists and modellers. The most recent meeting of the group was held in the two days prior to the BIOPROTA Workshop and participants therefore included both IUR and interested BIOPROTA members.

Interaction matrices are being developed by the group for both terrestrial and freshwater environments for a number of radionuclides of interest and these will form the basis of a report that makes recommendations on how to improve assessment models. The report is due to be produced by the end of 2009.

During the meeting, selenium IUR members assisted with the BIOPROTA SeSoPla project and the development of the NHB knowledge quality assessment questionnaire. Many of the participants have also volunteered to assist further through provision of individual views to the final questionnaire.

Future activities will see the focus of the group move away from academic matters toward practical applications. Particular study areas that may be of future interest to BIOPROTA were suggested including the long-term impact of shallow disposal facilities and the use of interaction matrices as a means of auditing current model structures.

3.3 EMRAS II NORM and Legacy Site Working Group

The newly formed NORM (Naturally Occurring Radioactive Material) and Legacy Site Working Group within the EMRAS II project was introduced by Danyl Perez-Sanchez (CIEMAT). As with the Waste Disposal group, the NORM working group first met in January 2009 and will continue until 2011.

The aim of the group is to develop reference approaches for assessments of nuclear legacy NORM sites such as those associated with uranium mining and the phosphate industry and, through this, provide a mechanism to help determine options for remediation, taking into account the economic situation. It is intended that, through the Working Group, developed countries will provide knowledge and assistance to developing countries. In return, information from the history of site monitoring may be useful to validate components of the assessment models.

The group currently has 29 participants, all of whom are from technical support organisations or regulatory bodies. It is hoped to encourage wider participation of organisations and experts who have largely implemented and completed remediation projects.

Diverse NORM situations are of interest due to historical discharges occurring to marine and freshwater environments, plus atmospheric discharges and terrestrial activities (building, disposal etc.) resulting in contaminated land. The NORM issue is therefore diverse both geographically and technically.

Timeframes for NORM assessments are difficult to define as they depend on the particular scenario, but can range from relatively short-term for routine and emergency situations through to the long-term (e.g. waste disposal).

Three main areas of focus are being considered by the group. These include:

- comparison of alternative models for specific scenarios;
- evaluation of models against independent data: and,
- development of guidance in light of the results.

It is also intended that the approach will be applied to a practical situation to test its applicability.

In discussion it was noted that the NORM Working Group could readily link to BIOPROTA through the proposed U-238 project (see Section 5.3). The availability of guidance from the US on the remediation of soils was also raised by Maryla Wasiolek with the suggestion that this could be used as a basis for further development of guidance by the group.

Finally, it was noted that the previous EC Phare projects gave an overview of uranium liabilities pilot remediation projects, which detailed remediation efforts to date and further remediation requirements. The output from the projects is documented in various reports, which should be in public domain. If accessible, these would provide a large amount of data relevant to the working group.

3.4 Update on PROTECT and the EMRAS NHB Working Groups

Brenda Howard (CEH) provided an overview of the EC PROTECT and EMRAS NHB working groups.

Internationally there are a variety of assessment approaches available, all of which are multi-component in nature and many provide a tiered screening approach, which is consistent with the approach for chemical assessments.

ICRP Committee 5, established in 2005, aims to develop an assessment approach comparable to that for man, and compatible with approaches for protection of the environment from conventional contaminants, based on reference animals and plants (RAPs). In developing the approach, both routine release and emergency scenarios are being considered. The approach, as with others, requires a high degree of simplification as it is not possible to account for all exposure pathways for all biota.

PROTECT

The EC PROTECT project reviewed the available approaches to environmental assessments for radioactive contaminants and concluded that none can be considered comprehensive; thus it is often necessary to apply multiple tools to achieve a full assessment (for example, it was noted that the Environment Agency R&D 128 approach is the only one to consider noble gases). The EC ERICA Assessment Tool has the most developed database for use where no site-specific data are available, whereas the RESRAD method has a greater requirement for site-specificity, but has a greater overall functionality including the ability to undertake dynamic modelling.

These three tools are inconsistent, both in the risk quotients applied and in the prediction of dose rates, with each tool giving very different results for the same scenario. For all methods, the transfer components of tools were found to contribute most to assessment uncertainties. However, there is a need to more fully understand the reasons for the large differences in assessment results.

As a result of the review it was recommended that the ERICA Tool represents the most appropriate platform for implementing ICRP requirements and that this tool should be used by all EU Member States as the most effective tool available. However, the need to maintain and improve the tool was recognised, as was the need to provide training courses in its application.

A further PROTECT recommendation was that the focus of NHB protection should be at the population level: not the individual. The goal should be to protect the sustainability of populations of the vast majority of species, thus ensuring ecosystem function both now and in the future. Special attention may be required for keystone, sentinel, rare, protected or culturally significant species and, in all cases, measurable targets and advice on tolerable risks is required.

There was also a strong advocacy for linking radiation protection to chemical protection with the recommendation that internationally agreed approaches for the setting of environmental thresholds for chemicals should be applied in order to determine numeric criteria for protection. In developing assessment approaches and protection goals, it was stated that expert judgement should be avoided.

The PROTECT project applied a method similar to that for chemical assessments to identify a screening value that would allow the exclusion of most sites from further assessments. The approach applied was highly conservative:

- Relevant effects data were identified from the FREDERICA database, produced under the EC FASSET and ERICA projects, and were sorted and quality assured against set criteria to identify EDR10 values (the dose rate resulting in a 10% effect). In total, 105 relevant values were identified all of which were for chronic gamma exposure and, unlike the approach applied in the ERICA project to determine a screening level, only the lowest value for each species was selected for inclusion within the calculations. Selection of relevant data focused on reproductive endpoints as being most applicable to population protection.
- The EDR10 data were then plotted to give a species sensitivity distribution. Data indicated that vertebrates were more sensitive to radiation than invertebrates, and mammals were the most sensitive of all the taxonomic groups.
- A hazardous dose rate (HDR5) was then calculated on the basis of the dose rate giving a 10% effect on 5% of species.
- An assessment/safety factor, as required under EC guidance for chemical risk assessment, was then applied in order to derive a ‘predicted no effect dose rate’ (PNEDR). A factor of 2 was determined following consideration of five criteria (number of data, whether laboratory or field, endpoints, supporting evidence, and data spread).

The resultant generic screening level recommended as a result of this analysis was the same as that derived within the ERICA project – 10 µGy/h.

The fact that screening values are often applied incorrectly was also highlighted.

The Environment Agency of England and Wales use a screening value of 5 µGy/h, to identify sites at which further information is required, and an action level of 40 µGy/h, at which there is a statutory requirement to do more. In the US, the DoE recommends action levels of 10 µGy/h for native aquatic biota and 40 and 400 µGy/h, respectively,

for terrestrial animals and plants. In Canada, screening values of 10, 220 and 110 µGy/h are applied respectively for fish, terrestrial and freshwater invertebrates.

The PROTECT consortium met with representatives of ICRP Committee 5, the IAEA and the EC and all endorsed the use of a screening level and were reasonably happy with the PROTECT recommended value of 10 µGy/h. International consensus was therefore achieved. However, it was noted that some representatives voiced a preference for an upper action level (second benchmark) to be proposed that would help identify where more serious issues exist. This second benchmark was not agreed upon, nor the method for deriving such a value.

In order to move forward in the field, there is a requirement for international cooperation and more consistency in approaches in order to reduce variation in assessment results. More extensive biological effects data for key wildlife groups are also required so that screening values for different taxa may be derived – lower order organisms are often the most exposed and yet are screened against a number largely derived from mammalian data.

EMRAS II Wildlife Working Group

The EMRAS II Wildlife Working Group is divided into three sub-groups on modelling, transfer to wildlife and effects. The group is continuing the work of the previous EMRAS NHB working group and intends to include additional radionuclides and to incorporate dynamic modelling approaches.

The transfer group intends to produce the equivalent of TRS-364 on human food chain transfers, for non-human biota assessments, since transfers from the environment into biota contribute most to variability (results from the previous EMRAS model inter-comparison showed variation in biota concentration predictions spanned five orders of magnitude). A core drafting group was established in November 2008. The group is focusing on terrestrial, marine and freshwater ecosystems and a wide range of radionuclides and organisms. The remit of the group is to provide data (relating biota whole-body concentrations to environmental media) where such data are available. Where no data are available, values will not be derived and therefore numerous gaps are envisaged. Guidance will be provided on how to address data gaps.

In order to collate data for input to the NHB TRS, an online database has been developed (accessible through the PROTECT website - www.ceh.ac.uk/protect) to which contributions are welcomed. Data will be analysed and weighted means calculated to avoid undue bias as a result of single values.

It is intended that the output will be made available by 2010.

4. PARTICIPANT PRESENTATIONS ON RADIOACTIVE WASTE MANAGEMENT AND BIOSPHERE ASSESSMENT PROGRAMMES

The following sections provide an overview of the presentations provided by the various participants on their radioactive waste management and biosphere assessment programmes. PowerPoint presentations may be accessed via the BIOPROTA webpage (www.bioprota.com).

4.1 The SKB Biosphere programme

Three presentations were provided by SKB on their ongoing waste management programme at the Forsmark site in Sweden. The presentations began with Tobias Lindborg providing an update on landscape modelling for the Safety Assessment SR-Site. The approach to modelling future hydrology and solute transport at the site was then presented by Sten Berglund and Björn Söderbäck gave an overview of how site data can be applied to dose models, with an example from the SKB SR-Site assessment.

Landscape modelling in the Safety Assessment SR-Site

The Swedish disposal concept involves the emplacement of copper canisters, surrounded in bentonite clay, at a depth of 400-700 m depth in bedrock. Site feasibility studies have been finalised for two sites and it is anticipated that the final site will be selected this summer[2]. A construction licence application is due to be submitted late 2010. It is expected that construction will commence shortly thereafter.

For the purposes of the presentation, the Forsmark site was focussed upon. This site is located next to the Swedish nuclear power plant on a largely uninhabited shoreline area with low topography. A typical feature of the site is the development of new lakes due to continued land uplift. Shoreline displacement occurs at a rate of around 6.5mm per year.

A detailed site characterisation programme was concluded in 2008. Potential discharge areas (exit points) into the biosphere were determined from hydrogeological models. These exit points were the focus of detailed site studies in order to fully understand the characteristics of the areas for input into model development.

Shoreline displacement models were used to determine future landscape on the basis of land uplift and seabed topography. Release points are predicted to follow the shoreline as it develops towards the northeast and be focused on the lower lying areas. The various exit points are used to identify landscape objects (lakes, mires, etc.) that are linked on the basis of hydrological flows within the landscape model. Exit times and retention conditions vary as each landscape object develops.

The current interglacial period is being simulated as an analogue of future interglacials. It is important to note that this is only one representative potential future, based on an understanding of how the current site has evolved.

Carbon production estimates, important for dose predictions, are based on primary production and the types of vegetation that would be expected to occur under different climate assumptions. Glacial periods are a particular issue due to the changes in groundwater flow, and thus transport routes for radionuclides, that would be expected. Such periods would also affect land use. Interglacial periods are assumed to occur approximately every one hundred thousand years.

[2] **Note added after meeting**. Subsequent to the BIOPROTA meeting, Forsmark was announced as the selected site

Modelling of future hydrology and solute transport at Forsmark, Sweden

Hydrology and solute transport models are being used by SKB, not only to look at the long-term implications of a repository, but also to assist in the design of the repository through consideration of short-term consequences, e.g. depression of the water table local to the repository site.

The approach to modelling future hydrology and solute transport is to use current objects as analogues for those that may develop in the future. Retention processes are considered, both in bedrock and regolith deposits, and the output used in dose calculation models.

A number of hydrological models are applied:

- Deep rock models (e.g. Connectflow), which consider bedrock down to ~2000 m, are used to represent fracture statistics and groundwater flow in a simplified manner (interactions with surface waters are not considered);
- Surface/near-surface models (e.g. MIKE SHE) take account of the entire hydrological cycle and incorporate interactions between surface and ground water and meteorological processes; and,
- GIS surface models are employed in order to link landscape objects.

Models are supported by site characterisation studies that have included the analysis of samples obtained from both shallow and deep boreholes.

A number of different considerations arise in the development of surface hydrology models. For example, there is a need to consider the development of new hydro-geological objects that may differ from those of the present day, such as the development of deep lakes compared with the current shallow lakes. Water balances of new terrestrial areas generated through land uplift are also of importance as are considerations of release mechanisms into landscape objects. For example, where radionuclides are released due to up-welling through benthic sediments they may have very different behaviour compared with releases to littoral sediments.

Regional models have been developed for areas where multiple exit points are predicted to enable greater focus on radionuclide transport over smaller time steps. Stratigraphical models are also used where particular focus is required on landscape development in association with Quaternary deposits (e.g. lake development).

When considering landscape development over time, water balances can be investigated. Although the overall water balance would be expected to remain similar, the exchanges between different compartments may differ, particularly in relation to climate and this can be important input to dose assessment models.

In discussions it was noted that it would be interesting to see continuity in the models developed by SKB and Posiva due to the proximity of the proposed repositories. Further detail on modelling the Forsmark site is documented as part of the SKB main report.

Proceeding from site data to dose model

In discussing how dose models can be developed on the basis of site data, there was a focus upon the lake ecosystem at Forsmark, which is reported in a Limnic report published as part of the SKB report series.

As previously noted, conceptual models of the different ecosystems have been used to identify potential release areas, thus providing focus for site investigations. The output

of the site investigations is then used to inform the overall safety assessment and environmental impact assessments, etc.

Site investigations at Forsmark were extensive, taking into account the regolith, climate and surface hydrology, chemistry, biota and human land use, resulting in the production of a large number of detailed reports.

At the landscape level, a digital elevation model has been developed which takes account of, amongst others, the distribution, depth and stratigraphy of the regolith layer from which landscape objects such as lakes can be identified. For lakes, detail on the bathymetry, sediments and habitat distributions have been taken into account in models and used as the basis for describing the transport of elements through a mass balance approach. This in turn enables the role of lakes in the transport of radionuclides to be considered at the landscape level.

Mass balances have been determined for 64 elements in a number of different lakes and the behaviour of some detailed:

- With the exception of chlorine and iodine, which occur mainly in the dissolved phase, sediments contain the majority of elements (e.g. thorium and uranium, which enter lakes via surface waters);
- Carbon and calcium are the main components of the biotic compartment;
- Lakes are largely autotrophic so the inflow of carbon is largely similar to the outflow. However, the largest pool of is within primary producers, whereas for phosphorus, the main pool is within consumers.

The detailed information gained on element mass balances in lakes has been an important component in the development of a radionuclide model, which consists of four sub-models. Radionuclides enter landscape objects either from the lower regolith or as a result of flow from other landscape objects. In total, the model takes account of around 240 parameters, all of which can be time dependent or independent and all of which are based on some form of site data. Succession of landscape objects is accounted for through knowledge on the lake properties, such as water depth, taking land uplift into account.

4.2 Update on the licensing process for the Yucca Mountain Repository

Maryla Wasiolek, speaking on an individual basis rather than as an organisation representative, gave an overview of developments in the licensing process for the Yucca Mountain repository in the United States.

The biosphere model developed for the repository safety assessment has not essentially changed over the last five years, although a few minor amendments have been made. The model provides biosphere dose conversion factors applied to a simple well scenario for which contaminated groundwater is extracted for irrigation purposes. In comparison with the biosphere model, geosphere considerations are complex.

In the US, the DoE is the agency that owns all radioactive waste and, therefore, when spent nuclear fuel is removed from reactors, the DoE should take possession and is responsible for disposal although, at present, no disposal facility is available.

In June 2008, a licence application submission was made and this was reviewed by the NRC until September 2008 to ensure that all components required for a detailed review were included. The submission passed this initial review (i.e. it was docketed) and so the formal review process began, as did a parallel but separate hearing process before the Atomic Safety and Licensing Board, which allows views to be put forward by interested parties as to whether the licence should be granted.

The Regulator is currently drafting a Safety Evaluation Report and it is anticipated that further information requests will be made to support the technical review process. The report is due to be completed 18 months from the date of licence docketing.

The whole process follows precise legal rules. Petitions have been filed that detail contentions to Yucca Mountain and both the DOE and the NRC have an opportunity to respond prior to a further opportunity for petitioners to respond in return. No issues that have not been raised in contentions may be heard. Following this pre-trial process, all remaining contentions will be consolidated for hearing in what will be very much like court proceedings in front of three panels of judges. The aim of the hearings is to provide all necessary information to support a decision as to whether the construction license should be granted. The final licence decision will be made by the NRC following the outcome of the proceedings.

The process is expected to take between three and four years and is currently on schedule (although the Secretary of Energy has recently stated that the Yucca Mountain repository is not a viable method for spent fuel disposal).

Discussion

It was suggested during discussions that, although legal systems will vary from country to country, the overall process for licence applications is likely to have similarities. There may therefore be some merit in reviewing experience in the license application process in order to provide guidance on the basis of lessons learnt for those entering the process.

4.3 Current Biosphere Studies at ANDRA: the HAVL Project

Yves Thiry gave an overview of the ANDRA HAVL project that encompasses all biosphere investigations required under the 2006 Planning Act. The project encompasses a wide range of related programmes, including the environmental monitoring programme. The current focus is on the period up to 2012 at which a report is required to be submitted that will inform an important public debate on the French waste repository. The debate is planned for 2013.

Three key radionuclides have been prioritised (Cl-36, I-129 and Se-79) with the intention of reducing uncertainty relating to model parameterisation (e.g. Kd, transfer factors, translocation factors etc). The ability for models to better perform in relation to predicting radionuclide behaviour in relation to future ecosystem and climate change assumptions is also a priority.

Various research projects have been established to support the HAVL work programme, including:

- **Effect of climate on soil type**. A traditional BIOCLIM-based approach has been employed to predict soil evolution in relation to climate change in the long-term through consideration of analogue sites. Two climate regimes (one warmer Mediterranean and one cooler sub-glacial) were defined. Under the warmer climate, geochemical weathering will be a dominant process for soil evolution involving the hydrolysis of minerals. This is anticipated to result in the development of soils from the current calcareous brown soils to more red clay soils. Under the colder climate, de-carbonation would remain active, but the rate would be dependant upon precipitation. Drainage will be very important for soil development.
- **Foliar transfer of radionuclides in agricultural systems**. A joint ANDRA-IRSN study is being undertaken. Translocation is an important pathway, but data for the key radionuclides are limited. The study aims to determine translocation rates under both chronic and pulse contamination scenarios for the key radionuclides and

four agricultural crops (wheat, radish, beans and potatoes) under field conditions (in the Chernobyl exclusion zone). Contamination will be via spray irrigation at different stages of plant development. The project is ongoing throughout 2009.

- **Behaviour of selenium in soils**. A PhD study is underway to investigate the behaviour of selenium in soils (mobility and redox conditions) under a chronic contamination scenario. The source of contamination will be irrigation water and the aim is to evaluate the important parameters controlling mobility in soil such as biological activity, organic matter content and pH. It is also planned that the kinetics of redox reactions will be investigated. A second PhD study will look at the relationship between selenium speciation, mobility and bioavailability and will investigate the influence of abiotic parameters on speciation and the impact of vegetation (including agriculture, pasture and forest). Output will include soil-plant transfer factor data.
- **Chlorine pools and cycling in terrestrial environments**. Three different and complementary scales (national, regional and local) are being focused upon in relation to chlorine research. National-scale research will look at the effect of deposits (both atmospheric and litter fall) and soil type upon chlorine residence times. The regional scale studies are investigating how chlorine behaviour differs between different ecosystem types (forest, agriculture and pasture). Finally, local scale studies will involve determining the distribution of chlorine between soils and vegetation and flux quantification.
- **Environmental Monitoring programme**. A large scale programme is currently underway that aims to establish an environmental sample bank plus supporting database over the long-term (around 100 years). It is intended that this will provide a detailed account of the current environment and its functions, and identify any sensitive or vulnerable ecosystems.

A number of areas of interest for future collaboration within BIOPROTA were also suggested, including:

- Continuation of the Cl-36 project to include a model-data inter-comparison to validate models;
- Development of the C-14 project to include dose calculations (similar to those undertaken for Cl-36);
- Establishing a working group to review toxic chemicals (As, B, Hg, Pb, Ni, Cr);
- Organisation of a workshop on radium and a separate workshop on the GBIZ to include experts from outside the nuclear field; and,
- Organisation of an international conference on the key radionuclides (iodine, selenium and chlorine), which again should be open to experts outside the nuclear field. It was suggested that such a conference could be considered in the longer term (e.g. 2012).

4.4 Recent Developments in Treatment of the GBI in the SKB Safety Case

The migration and accumulation of radionuclides in weathered rocks and deposits above base rock formations but below surface soils[3] is complex because of the very heterogeneous hydro-geochemical properties. The selection of representative sorption coefficients is such media is therefore problematic.

[3] This region is sometimes referred to as the geosphere-biosphere interface (GBI), though the definition may vary in detail from site to site.

Lara Duro (Amphos) presented work being carried out for SKB on an integrated approach for quantitative study of radionuclide migration through the Quaternary sediments at the Forsmark site (Sweden). The objectives of the study are:

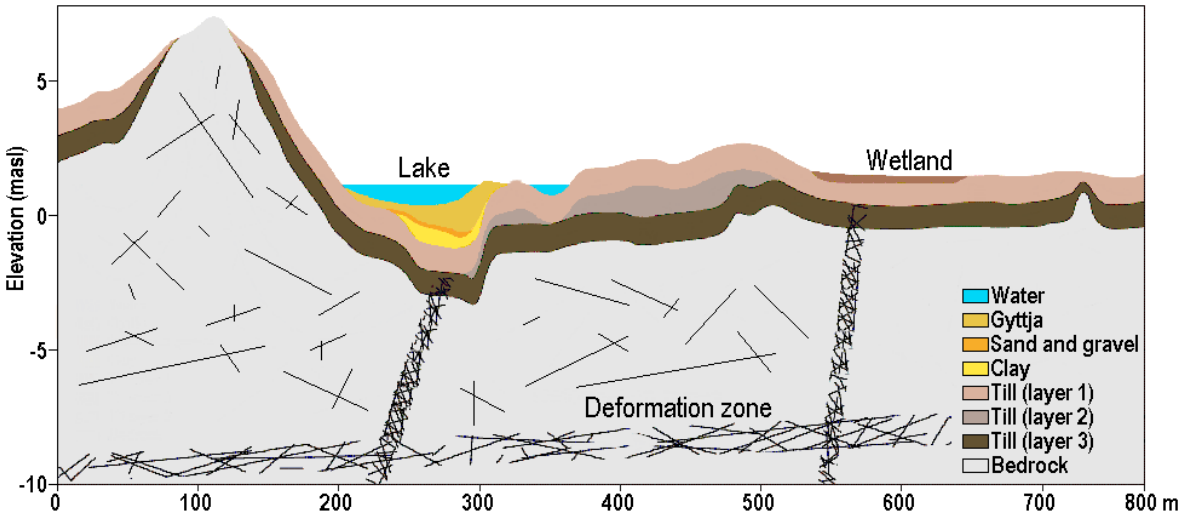
- Assessment of the retention capacity of the Quaternary deposits via a coupled transport model: bridging the gap between geosphere and biosphere model domains; and,

- Evaluation of effective parameters to assess radionuclide retention in the Quaternary deposits.

Lara described the topography and other relevant GBI features of the site notably:

- Glacial till is the most abundant outcropping Quaternary deposit (~75% of surface extent);
- Highly variable thickness: 0-10 m;
- Sand with variable amounts of boulders, and of clay;
  - Significant amounts of $CaCO_3$
  - Variable hydraulic conductivity:
    - $5 \times 10\text{-}9$ m·s^{-1} (clay rich zones)
    - $5 \times 10\text{-}5$ m·s^{-1} (sandy-gravel levels)
    - $1 \times 10\text{-}4$ m·s^{-1} (uppermost level)

A diagram of the conceptual model is shown in the figure below, including major features such as deep groundwater flows along main deformation zones and shallow groundwater flows towards streams, lakes and the Baltic Sea.



In the first phase of the project, U, Sr, Se, Cs and I were selected for conceptual modelling and qualitative understanding. This selection covered a wide range of geochemical behaviours and processes: adsorption onto mineral surfaces, co-precipitation, cation exchange. Then U, Cs, Sr and Ra were selected for quantitative coupled groundwater flow and reactive solute transport simulations. Retention/mobilisation processes for these elements are well documented in literature and they can be implemented into reactive transport calculation tools.

Lara then outlined a 2D numerical model for flow and transport in till deposits, including the key processes and data for each element considered. Using this detailed approach, it is possible to simulate the breakthrough of elements to the soils and sediments lying above the till, and to calculate the effective sorption and retardation coefficients over the volume of the till. The key point is that these effective sorption and retardation

coefficients can be used is simplified transport models used in overall assessment calculations.

4.5 Dilution and Long-term Dose Calculations

Shulan Xu (SSM) gave a presentation concerning the size of contaminated surface area associated with one leaking canister and spatial discretization in long-term dose assessment modelling. Such issues arise due to uncertainties in estimating activity concentrations in the far future. In order to ensure that dose assessments and risk analyses are defensible, a detailed understanding of the important processes governing groundwater movement (discharge) and radionuclide transport is needed.

SSM have initiated a research and development project in order to establish an independent performance assessment modelling capacity to enable SKB models to be critically analysed through the testing of model assumptions and the ability to reproduce dose calculations.

Groundwater flow patterns have been investigated and discharge areas are predicted to occur in low topographic areas, largely associated with lakes, rivers and wetlands. The discharge points are also associated with a thick soil layer and bedrock fracture zones which enable groundwater to exit the geosphere. Therefore, the contaminated area due to leakage from damaged canister(s) can be estimated from flow and transport modelling including dispersion and advection in rock fractures. As a result of the project both numerical and analytical tools for groundwater modelling have been developed.

A number of publications are available which underpin the model development, including:

- Marklund L, Wörman A, Simic E, Geier J, Dverstorp B (2008) ”The impact of different geological parameters on transport of radionuclides” Nuclear Technology 163 165-179.
- Wörman A, Packman A I, Marklund L, Harvey JW, Stone S (2006) ”Exact three-dimensional spectral solution to surface-groundwater interactions with arbitrary surface topography” Geophys Res Lett 33 L07402 doi:10.1029/2006GL025747.
- Wörman A, Packman A I, Marklund L, Harvey JW, Stone S H (2007) ”Fractal topography and subsurface water flows from fluvial bedforms to the continental shield” Geophys Res Lett 34 L07402, doi:10.1029/2007GL029426.
- Xu S, Wörman A, Dverstorp B (2007) Criteria for resolution-scales and parameterisation of compartmental models of hydrological and ecological mass flow in watersheds Journal of Hydrology 335 364-373.
- Xu S, Wörman A, Dverstorp B, Klos R, Shaw G and Marklund L (2008) SSI's independent consequence calculations in support of the regulatory review the SR-Can safety assessment. SSI Report 2008:08.

Further model development is planned. The current model is focused on particle tracking and this will be developed for diffusive transport processes. Field studies are also planned to further increase understanding. Bounding calculations will also be undertaken to establish a step wise approach and a consensus for PA modelling.

4.6 Stable Element Transfer Factors for Game and Farm Animals

Steve Sheppard gave an update on the ongoing stable element survey being undertaken by ECOMatters to determine transfer factors for game, farm animals and agricultural and domestic crops. The survey began as a result of a new analysis

method becoming available which enables multiple materials to be analysed in cost effective method. The method allows a whole suite of elements to be analysed simultaneously.

In 2008 the survey was extended to include a greater range of animal products (milk, eggs and meat) and a greater number of fish were sampled from a variety of lakes (shield and tundra). Domestic animal samples were obtained from both coastal and mid-continent sites. The survey also extended the analysis of vegetable crops to include, where possible, matched agricultural and garden produce.

Iodine transfer data arising from the 2008 survey are detailed below. Data on the transfer of iodine from water to fish in particular showed little variation.

Parameter	GM	GSD
Transfer factor, Fish/water (L/kg)	37	3.2
Transfer factor, Geese (d/kg)	1.1	2.0
Transfer factor, Deer (d/kg)	0.0051	2.0
Concentration ratio, blueberry/soil (unitless)	0.0039	
Transfer factor, Chicken (d/kg)	0.28	
Transfer factor, Egg (d/kg)	2.7	1.7
Transfer factor, Milk (d/L)	0.043	3.1
Concentration ratio, Plant/soil (unitless)	0.013	2.9
Soil/water, Kd (L/kg)	0.74	2.3
Sediment/water, Kd (L/kg)	1200	4.8

Transfer factor data for feed to eggs and feed to milk derived for a range of elements were found to be in good agreement with those put forward in the TRS-364 revision and thus provide a degree of data validation.

For vegetable crops, efforts were made to obtain paired garden and field produce. Resultant soil to plant concentration ratios for selenium, iodine and chlorine are detailed below. For the majority of elements, uptake into leafy crops was greatest; however, in the case of selenium, uptake into seed crops was highest. Uptake into fruit was approximately half that of leafy crops.

Element	Concentration ratio			
	Leafy vegetable	Fruit	Root crop	Seed crop
Iodine	0.033	0.006	0.009	0.008
Chlorine	25	12	7.8	3.2
Selenium	1.0	0.4	0.7	1.6

The survey is ongoing in 2009 and beef, pig, lamb and a range of domestic birds will be analysed. It is also intended that data will be converted to provide results on a dry weight basis.

4.7 Overview of Current Status of Japanese Geological Disposal System

Keiichirou Wakasugi (NUMO) gave an overview of the Japanese programme for geological disposal of radioactive waste. The programme began in 1976. No specific site has been selected to date, but it is required under law that the disposal of TRU (transuranic waste) will be at a depth of at least 300 metres.

As of April 2008, NUMO became the implementer for the disposal of TRU waste. Once a candidate site comes forward a decision will be required as to whether the site will dispose of one waste category or combined LLW and TRU.

The Japanese Nuclear Safety Commission is required to provide basic scenarios and safety criteria for LLW disposal. The disposal concept for LLW is for shallow underground disposal and three types of safety assessment scenarios are required – base, variant and extremely low probability. The base scenario considers uplift and erosion, both of which can have a significant impact on total dose estimates. There is no cut off on the assessment timeframe so uplift may eventually bring waste closer to the surface, resulting in an overall change from reducing to oxygenated conditions and an increased likelihood that the repository will be disturbed.

There is a large degree of uncertainty associated with determining future human activities and the types and likelihood of different activities that should be considered in the safety assessment is an issue currently under discussion. Of particular concern is whether urbanisation of current agricultural areas should be considered. Such activity would involve excavation, leading to increased dose estimates.

The Nuclear Safety Commission will develop the base scenario, taking into account most likely events and processes. Further work is on-going in relation to variant and very low probability scenarios.

4.8 Recent Advances in BSA-2009 Biosphere Assessment at Posiva

Ari Ikonen, Thomas Hjerpe and Jani Helin presented.

The Finnish disposal site (Olkiluoto) was selected in 2000 and a decision in principle was granted by the Government and Parliament in 2001. A construction licence will be applied for in 2012 followed by an operating license submission in 2018.

At present, the ONKALO rock characterisation facility is being constructed and it is anticipated that the final depth will be reached within 1 year. The access tunnel was, as of the end of April 2009, at a length of around 3500 metres and a depth of 340 metres below surface level.

Regulatory guidance has recently been updated by STUK such that the period over which the biosphere assessment should be focused has been amended from ‘several thousand years’ to a ‘reasonably predictable era’. It is still required that the assessment should take account of current ecosystems, rather than speculate what may occur in the future; however, land uplift and the emergence of new land areas are to be considered. Non-human biota assessment criteria no longer state the need to demonstrate ‘no decline in biodiversity’, but rather that typical doses should be determined.

Ecosystem characterisation

The ecosystem monitoring programme around Olkiluoto is comprised of continuous monitoring programmes plus ‘spot’ sampling campaigns (e.g. biota sampling). The monitoring of forest ecosystems comprises a large part of the overall monitoring programme. Remote sensing has been applied to obtain a wider picture of the surrounding environment.

Monitoring plots are being lost due to the industrial activities on the island and, as a result, no new sampling plots will be sited mid-island, but will instead be focussed on the eastern side. Extensive landscape change is evident as a result of the industrial land use and land uplift is also evident.

A water quality mapping exercise was conducted in July 2008, which involved several thousand monitoring points at which temperature, nutrient status and sedimentation rates were established. Diving transects were also undertaken as a means of collecting

samples of sediments, flora and fauna. The exercise provided data for a snapshot in time, but it is intended to conduct further monitoring in order to determine variation. For example, it is intended that there will be a two year monitoring campaign to determine sedimentation and re-suspension rates.

Biosphere modelling

Ecosystem characterisation feeds directly into the biosphere modelling programme. Site data are combined with analogue data and that from literature review, analysed and used as input to the development of transport matrices that then form the basis of ecosystem models. The use of site data is valuable in supporting process understanding.

Future human activities are predicted on the basis of land use (forest, agriculture, urban areas etc), which is in turn predicted on the basis of soil/sediment typology.

A linear model is used to predict releases from the geosphere to the biosphere, but this is subject to uncertainty, particularly with regard to the small areas of release that are predicted. Investigations are therefore underway to identify any modelling artefacts and to improve upon the modelling process.

A tiered screening approach is applied to radionuclide transport. At Tier 1, radionuclides are screened according to their radiotoxicity. At Tier 2, radionuclides are screened by applying very conservative ecosystem-specific screening models. This screening approach has been applied to all relevant results from calculation cases in the near-field and geosphere radionuclide transport modelling, resulting in a list of around 14 radionuclides that require consideration in the biosphere safety assessment.

Dose assessment approach

The human dose assessment approach has been improved to achieve harmonisation with the ICRP dose concept of assessing doses to the representative person. Average intake rates are combined with cautious habits data (occupancy, use of local resources), on the basis of present day conditions. Doses are calculated through consideration of the geometric properties of the landscape model. Biosphere objects are modelled individually (e.g. lakes, rivers, agricultural land) to determine object-specific radionuclide concentrations that can then be used to determine activity concentrations in food items. The number of exposed persons is limited by the ability of the ecosystem to sustain the population through production of food, availability of drinking water and size of suitable residential areas. It is cautiously assumed that all consumed food is produced in the local area.

In the case of non-human biota, organisms will be grouped according to functional groups and typical doses calculated. For those organisms that move between ecosystems (e.g. migratory animals moving between forest and agricultural land), the dose rate calculation also takes the proportion of time spent in each compartment into consideration. This approach is being taken to ensure that dose rates to biota are calculated in a way that matches, as closely as possible, the approach for humans.

4.9 Recent NDA (RWMD) Biosphere Studies

Mike Thorne gave an overview of recent biosphere work by the UK Nuclear Decommissioning Authority (NDA) Radioactive Waste Management Directorate (RWMD).

No site has yet been selected in the UK for the geological disposal facility and therefore site-generic work is being conducted. Biosphere assessment studies are required in

order to feed into the development of disposal concepts and to make ready to compare potential sites. Six geological contexts that are generally applicable in the UK are being considered in the current preparatory phase of work. These range from salt and mud rocks with retention times of millions of years, through to more Swedish-type hard rocks with transport times of a few hundred years. Due to the different characteristics of the potential host rocks, the radionuclides of importance would be expected to differ.

Screening has been undertaken, based on the six geologies and the UK inventory of ILW and HLW including spent fuel, to identify the main radionuclides of concern. For each of these radionuclides the aim is to describe the current state of understanding on biosphere transport processes and modelling approaches and that identify research requirements. This has been completed for four radionuclides (C-14, Cl-36, Tc-99 and I-129). Chlorine-36, Tc-99 and I-129 were grouped due to commonalities. The most important pathways have been investigated and the main uncertainties/sensitivities identified. The main focus for 2009 will be Se-79. Additional work may be undertaken on Np-237 and other higher actinides.

Work has also been undertaken to identify the key FEPS for climate change, which builds upon previous landscape studies. The aim is to consider whether climate transitions affect dose factors and to identify transition FEPs that could enhance impact. In UK context, the base case involves gradual warming followed by gradual cooling over a period of 50,000 to 160,000 years. Alternative cases are also being considered. The impact of sea level rise on coastal sites is being considered as are glacial effects. The behaviour of key radionuclides is being considered in relation to the main climate change time steps and the time period in which radionuclides are predicted to enter the biosphere.

Catchment-scale modelling is an important component of the biosphere programme – it is important to ensure confidence in the representation of the hydrological cycle. A physically-based catchment model approach is being employed, which takes account soil type and other factors that affect water migration.

Previously the SHETRAN model has been used for catchment-scale modelling. However, MIKE-SHE/MIKE11 is also being evaluated in a test case of a catchment in West Cumbria for which real data are available (e.g. topography, rainfall, land use etc.). SHETRAN will also be evaluated on the same test case to allow both models to be compared on a level playing field. The final choice of which model to use would be dependant upon the results of this comparison and the site selected.

Chemotoxics

In the UK there is regulatory guidance that states the need to consider non-radiological hazards associated with the geological disposal facility and a qualitative assessment of exposures, taking into account synergistic effects with radionuclides, is therefore being undertaken for the headline contaminants. The transport of chemotoxics from the geosphere to the biosphere has been modelled in largely the same way as for radionuclides.

Beryllium, cadmium, chromium, lead and uranium have been prioritised as key chemotoxics and their release to the biosphere has been modelled, taking account of speciation.

Three cases have been considered:

- Case 1: Solubility unlimited with no sorption;
- Case 2: Solubility limited with no sorption; and,
- Case 3: Solubility limited with near-field sorption.

Two variant cases are considered for case 2 and case 3:

- A: Cellulose degradation products (CDP) enhance solubility; and,
- B: CDPs do not enhance solubility.

Results of Case 1 indicated that all chemotoxics were of concern for both groundwater and well irrigation pathways. Only chromium was of importance in relation to inhalation, and only under Case 1. Fewer chemotoxics were of importance under Cases 2A and 3A and none failed the screening criteria for Cases 2B or 3B.

Uranium, cadmium and lead can all cause effects on kidneys and therefore synergistic effects were considered for the oral ingestion pathway. Similarly, lead and radionuclides have been linked with cancer formation and therefore their potential synergism was considered. All chemotoxics were considered in relation to radionuclide impacts in the case of lung cancer induction.

Under Case 1, severe adverse effects on kidneys could occur, mainly as a result of lead, but with some influence from uranium. Nephrotoxicity was also important under Case 2A, although lead concentrations were predicted to be a factor of two lower; hence impacts would be lower when compared with Case 1. Nephrotoxicity, under Case 3A, is considered unlikely.

As with nephrotoxicity, cancers resulting from lead ingestion were considered unlikely for Case 3A, but a possibility for both Case 1 and Case 2A. The mechanism for the induction of cancers is unknown, but non-genotoxic mechanisms have been proposed, including inhibition of DNA synthesis and repair, alterations in cell-to-cell communication, and oxidative damage. It is considered possible that multiplicative effects could occur. For example, radiation-enhanced sensitivity in individuals may occur where DNA repair mechanisms have been impacted as a result of exposure to lead.

Lung cancer induction was only important in relation to chromium (presumed to be present in the more potent hexavalent form) in Case 1. If present in the hexavalent form, chromium could lead to DNA damage, which could be additive to DNA damage caused by exposure to radionuclides.

NDA Bibliography

A number of reports have been (or will soon be) made publicly available on the NDA web-accessed bibliography that relate to the biosphere studies outlined:

- Biosphere assessment approach
  - Egan M J, Smith G M, Thorne M C and Walke R C (2008). NDA RWMD Biosphere Assessment Studies FY2007-2008: Biosphere Assessment Approach. Quintessa Report for NDA RWMD, QRS-1378E-2, Version 1.0, May 2008.
  - Egan M J (2009). NDA RWMD Biosphere Assessment Studies FY2008-2009: Context and Approach to Future Biosphere Assessment Calculations. Quintessa Report for NDA RWMD, QRS-1378K-2, Version 1.0 (Draft Final), March 2009.
- Catchment-scale modelling reports
  - Towler G and Thorne M C (2008). NDA RWMD Biosphere Assessment Studies FY2007-2008: Geosphere-Biosphere Interface Zone Issues, Catchment-scale Modelling and Distributed Biosphere Modelling. Quintessa Limited report to NDARWMD QRS-1378E-3, Version 1.0, April 2008.
  - Towler G and Thorne M C (2009). NDA RWMD Biosphere Assessment Studies FY2008-2009: Catchment Scale Modelling – Evaluation of MIKE SHE.

Quintessa Limited report to the NDA RWMD QRS-1378K-5, Version 1.0 (Draft), February 2009.

- Climate change and landscape evolution reports
  - Thorne M C and Kane P (2006). Development of a Series of Narratives for Climatic and Landscape Change. Mike Thorne and Associates Limited Report to UK Nirex Ltd MTA/P0011a/2005-1: Issue 2.
  - Thorne M C (2008). NDA RWMD Biosphere Assessment Studies FY2008-2009: Key FEPs in Climate Change Transitions. Quintessa Limited report to NDA RWMD QRS-1378K-3, Version 1.0 (Draft), December 2008.
- Key radionuclides and contaminant 'stories'
  - Thorne M C (2009a). NDA RWMD Biosphere Assessment Studies FY2008-2009: Identification of Key Contaminants. Quintessa Report for NDA RWMD, QRS-1378K-1, Version 1.0, December 2008.
  - Thorne M C and Limer L M C (2009). NDA RWMD Biosphere Assessment Studies FY2008-2009: The Biosphere Transport, Distribution and Radiological Impact of Cl-36, Tc-99 and I-129 released from a Geological Disposal Facility. Quintessa Report for NDA RWMD, QRS-1378K-4, Version 1.0, April 2009.
- Chemotoxic reports
  - Wilson J, Thorne M C and Towler G H (2009). Treatment of Chemotoxic Species: Quantitative Human Health Risk Assessment. Quintessa Report for NDA RWMD, QRS-1378M-1, Version 1.1, April 2009.
  - Thorne M C and Wilson J (2009). Treatment of Chemotoxic Species: Review of Additive and Synergistic Effects. Quintessa Report for NDA RWMD, QRS-1378M-2, Version 1.1, April 2009.

5. THE 2009/2010 BIOPROTA WORK PROGRAMME

The following section outlines the projects continuing into 2009 and their anticipated delivery schedule and identifies those project ideas generated throughout the duration of the workshop that will be taken forward to proposal generation.

5.1 Completion of Current Projects

The delivery schedule for ongoing BIOPROTA projects is outlined in brief below.

Carbon-14 modelling

The project has progressed in accordance with the initial project plan. The final draft report is due to be made available late summer / early autumn.

Chlorine-36 Modelling (Phase II)

The final report for Phase II is due to be completed by the end of September with the anticipation that it will be published and distributed by the end of December. Recommendations for further work may be made as a result of Phase II.

Selenium-79 in Soils and Plants

The Selenium project has been slightly delayed due to delayed input of some research reports sponsored by NAGRA. However, it is anticipated that the project can still be reported within the initial work programme deadline of end September.

Non-Human Biota Sensitivity and Knowledge Quality Assessment

The Knowledge Quality Assessment questionnaire will be distributed, following revisions in line with comments and suggestions from the IUR meeting participants, by the end of May. It is then intended that a workshop will be scheduled for September to discuss the evaluation (and further sensitivity analysis results) and what these mean in context. The project report will then be completed by the end of December.

Site Characterisation

The information received on experience in site characterisation experience will be reviewed in the context of the previous BIOPROTA report. Since the number of examples available so far is quite limited, the results are likely to feed into next steps rather than a publication at this stage.

5.2 Proposals for Current Project Extensions

A number of potential extensions to current projects were identified for which proposals may be distributed. Each of these is outlined in brief below.

Iodine-129 in peat bogs

The research paper produced on the I-129 in peat bogs project has been made available to sponsors and will be submitted for publication shortly. A further continuation of this research may be appropriate and ANDRA will consider and inform on this.

Chlorine-36

During the course of the workshop, the proposal was made that the chlorine-36 project could be extended to include the use of real site data as a means of model validation. Group participants are requested to consider this further and draw together a proposal if deemed appropriate. In addition, it was suggested that a peer reviewed journal paper be prepared based on the results of the Phase 2 work.

BIOPROTA Database

Stage 2 of the BIOPROTA database development requires implementation to take account of the different levels of quality assurance that are required.

It was suggested that Stage 2 should include the development of different accessibility levels for folders so that owners can determine access. Electronic data sets could be stored, for example related to TRS-364 and its successor, so all relevant assessment data could be accessed from one source. Brenda Howard therefore recommended that the authors of the TRS-364 datasets (plus the scientific secretary for EMRAS) be contacted to determine if current databases could be accessed for this purpose.

A proposal outlining Phase II will therefore be drafted by Thomas Hjerpe for distribution to the sponsoring committee. Each possible option will be set out alongside a cost estimate.

User accounts for the current prototype will also be provided to all sponsoring organisations, not just those that funded Phase I, to allow examination of database functionality. All organisations are requested to provide feedback on possible applications within their organisation.

Site characterisation

Once the review of data provided in response to the current project has completed, it was suggested that further efforts could be made to identify relevant information from radionuclide-specific reports on the key parameters / data that are required for assessment models (e.g. stable chlorine in environmental compartments). This would result in a set of recommendations on what measurements should be included in characterisation programmes.

A proposal to further develop the site characterisation project will be produced and distributed by Graham Smith for consideration by sponsoring organisations. It was suggested by Ari Ikonen that this stage should also consider practicalities in monitoring and should be closely tied with the development of the BIOPROTA database to ensure that recommendations are made on how to derive reliable parameters.

Selenium-79

Work to date on the SeSoPla project has identified a number of areas of uncertainty. Recommendations for a future work programme may therefore be made as the project moves to completion.

5.3 New Proposals

As a result of the presentations made during the workshop, and individual ideas posed, a number of new proposal ideas were identified. These are described below and actions placed on individuals for proposal development where appropriate.

Uranium-238 series dose modelling

A proposal was distributed in 2008 by NNL that aimed at development of a new model, but there was insufficient take up to enable the project to move forward. However, it is apparent that there is still interest in U-238 series modelling, but more in relation to improving confidence in assessments using current models over the long-term than in the development of a single new model.

The interest in U-238 modelling is not focused solely on deep geological disposal, the following are also of concern:

- Delayed and long-term release of U-238 and daughters in groundwater resulting from near surface disposal of uranium and radium bearing wastes;
- Releases from uranium mining and mill tailing waste facilities, and waste dumps from NORM industries;
- Residual activity at legacy sites, such as those involved in the radium luminising industry.

The source of U-238 and daughters in the biosphere is not the primary concern since the assessment issues will be similar, for example, lack of understanding of the disequilibrium in the decay chain within Quaternary deposits and influence of redox conditions etc. There is a need to consider the full decay chain in order to fully address disequilibrium issues, including radon emanation in different environmental situations and taking account of environmental change.

It was therefore proposed that the initial stage should follow a similar mechanism to the selenium-79 project whereby the methods currently applied are compared and contrasted and processes evaluated in consultation with experts to determine those key for inclusion in biosphere models. It was proposed that lines of communication will be opened with those in both NORM and uranium mining communities.

A proposal outlining the main issues and proposed methodology will be drafted by Graham Smith and Danyl Perez-Sanchez and circulated to sponsoring organisations for consideration.

Radium Workshop

The proposal to hold a radium workshop to advance knowledge and understanding of the key processes and fate of radium in the environment was raised by Yves Thiry. This could bring together those involved in radioactive waste management with those with experience with legacy sites. It was proposed that such a workshop could be combined with the 2010 annual BIOPROTA workshop.

A proposal for the development of a workshop will be prepared and distributed by the Technical Secretariat.

Effective Kd

In discussion of Lara Duro's presentation of work for SKB, it was suggested that the same technique could be applied at other sites and to other heterogeneous parts of the system under assessment, such as the surface soil column, to determine effective parameter values. This would be most valuable for the most critical radionuclides for which sorption and retention is redox sensitive.

Participants are invited to contact Tobias Lindborg and Lara Duro with suggestions, copying the Technical Secretariat, for how to take this idea forward. According to the feedback, Lara Duro will prepare and distribute a proposal for consideration.

Licensing processes – lessons learned

The suggestion was put forward that experience in the licensing process could be compared and contrasted to determine whether relevant information can be gained on how to ensure site characterisation programmes are focused on the key areas to address issues encountered. Three crucial points were identified:

- how regulators define safety criteria;
- how operators produce safety cases to comply with safety criteria; and
- how to demonstrate compliance.

At present there is not sufficient universal agreement in these three fields and this is crucial for biosphere assessments.

Although considered an interesting topic, there was not sufficient interest expressed to justify proposal development at this time.

Chlorine, Selenium and Iodine Conference

The idea of holding an international conference on the key radionuclides chlorine, selenium and iodine was raised by Yves Thiry and there was overall agreement that this was a good idea, but it would require promotion. The suggestion was made that this be considered for 2012 and further thought will be given to this in the near future and proposals developed as appropriate. Please contact Yves with suggestions, copying to the Technical Secretariat.

6. ADMINISTRATIVE ISSUES

The following section outlines administrative issues discussed during the workshop.

6.1 Overview of the Sponsoring Committee Meeting

The current BIOPROTA Chair, Tobias Lindborg, gave an overview of the main points arising from the Sponsoring Committee meeting:

- Overall the committee was happy with current membership and no new target organisations were identified. It was noted that membership by additional regulatory authorities may be beneficial.
- Sponsoring organisations are requested to provide a link to the BIOPROTA website (www.bioprota.com) within their own organisation websites to promote the work of the forum.
- The current scope of activities was considered appropriate and no changes in direction are required.
- The administration of the forum works well and no changes to the activities of the Technical Secretariat are required.
- With regard to annual workshop arrangements, it was considered that more time should be made available to allow for detailed discussions between participants.
- The Sponsoring Committee appreciates the work of the IAEA's EMRAS II Working Group on Waste, and encourages BIOPROTA organisations to take note.

6.2 BIOPROTA Chair

Tobias Lindborg stepped down as chair of the BIOPROTA forum. At the suggestion of the Sponsoring Committee members, Yves Thiry (ANDRA) agreed to be the new chair for 2009/2010.

The contribution of Tobias to the running of the Forum over the last 2 years is gratefully acknowledged.

6.3 Sponsoring organisations

The current 2009 BIOPROTA Forum sponsoring organisations are listed below.

Organisation	Contact	Organisation	Contact
ANDRA, France	Yves Thiry	NRPA, Norway	Per Strand
BfS, Germany	Gerald Kirchner	NUMO, Japan	Keiichiro Wakasugi
CIEMAT, Spain	Cristina Trueba	NWMO, Canada	Paul Gierszewski
EDF, France	Lara Marang	Posiva, Finland	Ari Ikonen
JGC Corporation, Japan	Kunihiro Nakai	SCK.CEN, Belgium	Geert Olyslaegers
KAERI, Korea	Yongsoo Hwang	SKB, Sweden	Tobias Lindborg
Nagra, Switzerland	Jurg Schneider	SSM, Sweden	Shulan Xu
NDA (RWMD), UK	Simon Norris		

6.4 2010 Forum meeting

The next BIOPROTA meeting (BIOPROTA XII) will be held in, or near, Stockholm, Sweden in May 2010 (possibly week commencing 10th May) and will be hosted by SKB. It was proposed to extend the workshop duration by a day to allow for a field visit to the Forsmark site.

An initial proposal for the 2011 meeting to be held in Canada to coincide with the ECORAD Conference was made, but this will be further discussed, along with any other offers from members to host the meeting, during the 2010 workshop.

APPENDIX A: LIST OF PARTICIPANTS

Name	Organisation
Lara Duro	AMPHOS, Spain
Yves Thiry	ANDRA, France
Gerald Kirchner	BfS, Germany
Brenda Howard	CEH, UK
Almudena Agüero	CIEMAT, Spain
Cristina Trueba	CIEMAT, Spain
Danyl Perez-Sanchez	CIEMAT, Spain
Inmaculada Simón	CSN, Spain
Steve Sheppard	ECOMatters, Canada
Laura Marang	EdF, France
Pedro Carboneras	ENRESA, Spain
Duncan Jackson	Enviros Consulting, UK
Heather Forbes	Enviros Consulting, UK
Karen Smith	Enviros Consulting, UK, *BIOPROTA Technical Secretariat*
Graham Smith	GMS Abingdon, UK, *BIOPROTA Technical Secretariat*
Christian Tamponnet	IRSN, France
Kunihiro Nakai	JGC Corporation, Japan
Mike Thorne	MTA, UK
Keiichiro Wakasugi	NUMO, Japan
David Bytwerk	OSU, USA
Ari Ikonen	Posiva, Finland
Jani Helin	Posiva, Finland
Laura Limer	Quintessa, UK
Thomas Hjerpe	Saanio & Riekkola Oy, Finland
Maryla Wasiolek	own capacity
Catherine Van den Hoof	SCK.CEN, Belgium
Geert Olyslaegers	SCK.CEN, Belgium
Björn Söderbäck	SKB, Sweden
Sten Berglund	SKB, Sweden
Tobias Lindborg	SKB, Sweden
Ulrik Kautsky	SKB, Sweden
Shulan Xu	SSM, Sweden