BIOPROTA

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

Report of the Tenth BIOPROTA Workshop

Wettingen, Switzerland
7-9 May 2008

Hosted by NAGRA

VERSION 2.0 FINAL
JULY 2008

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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 1.0 Draft 13 June 2008 prepared by Enviros for review by participants.
Version 2.0 Final 17 July 2008 incorporating participant comments.

Contents

1. INTRODUCTION

1.1 Objectives of the Tenth BIOPROTA Workshop

The objective of the workshop was to update interested parties on the progress since the last meeting in May 2007 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 opened with a welcome from Frits van Dorp, Nagra, which was followed by introductions by each participant and agreement of the agenda.

1.2 Report structure

The remainder of this report provides:

- An overview of the progress made in 2007/08;
- A summary of presentations made by participants on their biosphere programmes and any challenges faced;
- An overview of the findings of a questionnaire distributed to BIOPROTA members and other interested parties; and,
- An overview of discussions of new tasks and proposals for the way forward in 2008/09.

1.3 Participation

There were 27 participants from 10 countries, representing a range of operators and technical support organisations. Participants are listed in Appendix A.

2. PROGRESS ON THE 2007/08 BIOPROTA WORK PROGRAMME

A number of tasks have initiated since the May 2007 BIOPROTA workshop. Presentations on each task were made to report on the aims, objectives and main findings (where applicable). For ongoing tasks, the anticipated completion date is provided.

2.1 BIOPROTA workshop on Se-79 behaviour in the biosphere

Graham Smith provided an overview of the findings of a workshop on the behaviour of Se-79 in the biosphere. The workshop was held in the two days preceding the annual workshop and was hosted by Nagra.

Selenium-79 is a long lived fission product, which due to its mobility and long half-life has the potential to reach the biosphere following release from deep geological waste facilities. Prospective dose assessments have also identified the radionuclide as one of the major contributors to long-term dose assessments.

The workshop was well attended by both selenium experts and representatives from radioactive waste organisations. A number of presentations were made, which will be published within the workshop report within which the main points of discussions will also be reported.

Selenium is of particular interest to those outside the radioactive waste organisations due to its natural occurrence in the environment for which selenium deficiency and toxicity are important issues. Selenium has a complex chemistry and can occur in different valency states, which are affected both by pH and Eh. There is also uncertainty surrounding the half-life of Se-79, which affects the specific activity and hence specific activity models.

A number of areas on which further work could be focused were also discussed including the improvement of databases on selenium and on model improvements. In relation to dose assessment models, some of the issues highlighted included:

- Volatilisation from soils and plants is often not included in dose models and this is potentially a significant mechanism for selenium loss from soils.
- Prediction of Eh and pH in the long-term is problematic.
- Compartmentalisation of models may be required to take account of the different forms that occur within soils. However, this would require more data than is currently available, but would enable better forecasts of future accumulation and root uptake.
- Changes in environmental conditions can result in rapid loss of selenium from areas in which accumulation has previously occurred (e.g. change in redox potential or drainage of mires for use as agricultural land). Such changes could result in large doses over the short term.
- Where groundwater is the source of Se-79 rather than well water and subsequent irrigation, consideration should be given to release into subsoil and subsequent migration into surface soil.

- Exposure to Se-79 is very much a result of the food chain rather than inhalation and/or external exposure. The main food pathways are liver, poultry and eggs. However, values used for consumption rates may be overly pessimistic in some instances.

- Account should be taken of the possible dilution of Se-79 with stable selenium and consequences for uptake into crops. In addition, the interaction of Se-79 with stable selenium should be considered (e.g. whether Se-79 is entering a selenium deficient or rich area, which could affect uptake into crops).

Other areas of research discussed included consideration of the ability to predict areas of accumulation in soil or deficiency on the basis of soil characteristics; use of sulphur as an analogue; measurements of volatilisation from soils and plants under different conditions; irrigation and resultant accumulation in arid environments; and, improved understanding of the effect of chemical form on the uptake of selenium into crops.

The preliminary conclusion of the workshop was that a working group should be created to consider the list of possible research areas and to prioritise and commission work as appropriate. Matthias Brennwald agreed to champion this working group to ensure progress through 2008/09.

2.2 Review of EMRAS deliverable TRS-364

A task has been funded by Andra and Numo to review the output of the TRS-364 IAEA EMRAS Working Group in relation to data requirements for long-term dose assessments for radioactive waste management facilities. Enviros have been commissioned to undertake the review once the final deliverable is made available (anticipated in autumn/winter 2008) and Carol Robinson briefly presented the aims and some initial observations arising from view of a current draft of the TRS-364 deliverable.

The initial TRS-364 document was limited to data for the temperate environment and focused on equilibrium conditions. However, the remit of the current TRS-364 working group was to address these limitations by focusing on available literature. A TECDOC will be produced that provides information of the source of the parameters included in the revised TRS-364.

A draft document was been received for review in the days prior to the BIOPROTA workshop. It is anticipated that this document will be revised for release towards the end of the year. The document contains parameters such as Kd, features on the use of analogues, information on processes governing mobility of radionuclides in soils, data on root uptake for different environments, transfer to animal products and fruits, and data for forest and freshwater ecosystems. Various climates are considered, but the availability of data varies considerably. Specific activity models for tritium, C-14 and Cl-36 are also included. [Elisabeth Leclerc added that new modelling approaches have also been proposed. For example, for soil retention, approaches other than the use of Kd have been considered that take account of pH etc. In addition, important cofactors have been identified such as pH and Eh, where applicable. A focus of the working group has therefore been to improve modelling approaches where appropriate and, where data are lacking, the working group have proposed a methodology for the use of analogues].

The aim of the preliminary review by Enviros was to look at the availability of data for the key radionuclides considered by BIOPROTA. From view of the current draft, data

summary tables were presented to give an overview of general data availability. For root uptake there is a varied range in data available – for example there is a particularly large range for technetium and minimal data on the transfer of selenium to plants. For animal products, there is a large scatter in the availability of data.

Overall there is a disappointing availability of data for non-agricultural ecosystems. For example, forest data are largely for radiocaesium and for freshwater there are significant gaps.

The current draft of TRS-364 has been made available for review and this provides a useful opportunity for BIOPROTA to provide feedback to the working group prior to the finalisation of the document. It was suggested that one approach may be to identify sources of data for those radionuclides of interest that may have not been considered by the working group to date and to make these available.

One particular issue highlighted by Matthias Brennwald in relation to the data in TRS-364 was the lack of information relating to different chemical forms (e.g. for selenium), which can have a large impact on environmental behaviour.

Additional comments and/or observations on the data included within the current draft that could be fed back to the working group are invited.

Work on the review of data will continue once the final TRS-364 document is published and it is anticipated that the findings of the review will be made available prior to the next annual workshop (May 2009).

2.3 Site characterisation

Site characterisation is costly and there is therefore a need to prioritise what must be measured and how to optimise surveys. Guidance on site characterisation was therefore included in the initial BIOPROTA work programme as Theme 3 and a report was produced and distributed in 2006.

Phase 2 of the site characterisation task been initiated under the sponsorship of Andra and NUMO and is aimed at updating the guidance provided in the current Theme 3 report. The work is being undertaken by GMS Abingdon in association with Amphos. An outline of the planned work programme was presented by Graham Smith.

The aim of the project is to identify lessons learned from site investigation programmes undertaken to date in order to determine: what has been measured, how measurements were taken (including how temporal and spatial variability have been addressed), and how the data derived are being applied in assessments. Aspects of particular interest in characterisation programmes include how climate, near surface lithostratigraphy, topography, water bodies, biota and human community (for example, human behaviour and land use) are addressed.

The initial stage will be to review current site characterisation programmes – those of Posiva, SKB and NAGRA through direct contact with these organisations. It is not intended that a critical review will be undertaken, more an exploration of the experience gained from each programme to identify what was useful, what was difficult, but also what was considered most necessary to support post-closure radiological assessments. Characterisation programmes for both shallow and deep disposal facilities are of interest.

Comments received following the presentation indicated broad support for this review. It was considered that the updated guidance document could help focus site characterisation programmes by identifying what the most relevant measurements. It was also noted that site characterisation programmes provide the basis for a thorough understanding of the site itself, as well as providing input to assessments. Other organisations will be contacted for inputs, and it is planned to complete the second review within 2008.

2.4 Iodine in peat bogs

Elisabeth Leclerc provided an update on progress with the research project into the behaviour of iodine in peat bogs. This was a co-funded experimental study with four partners (Andra, SKB, Posiva and NDA (RWMD)), which looked at the long-term sorption of iodine on organic matter in a Canadian peat bog contaminated with iodine some 15 years prior to the study. The experimental programme has been completed and results were therefore presented.

The study was comprised of three main topics:

- the transfer of iodine along the carbon cycle in the peat bog (plant uptake and speciation within the plant throughout the entire plant life cycle);
- the role of the redox potential on the migration and speciation of iodine in the peat bog; and,
- the relationship between the chemical structure of organic matter and the sorption of iodine through experimental studies using thermally matured peat.

Carex has been identified as containing relatively high concentrations of iodine in the peat bog and therefore this was the focus of study for the initial topic. Iodine is taken up during the initial growth of the plant, but it was also noted that transfer to leaves could occur from direct contact with peat water – i.e. iodine appears to become fixed to organic matter during the biodegradation process.

For the second topic, it was intended to investigate whether there was a link between the redox potential of the peat and iodine retention. However, problems were encountered during site investigation and this contributed to the inconclusive results obtained. Overall, redox potential was found to vary with depth, but iodine retention was primarily in the upper peat. It therefore proved difficult to establish a link between redox and the sorption of iodine and no publications have been submitted from this part of the study due to the inconclusive results. However, it will be fully reported on in the final study report.

For the third research topic, the elementary composition of organic matter was altered thermally. An evolution of organic matter (both chemical and physical) with temperature was evident and iodine sorption was found to be linked to this evolution. The physical composition of organic matter (i.e. surface area) was observed to be more important in determining iodine sorption than the chemical composition. However, increasing aromatic compounds within peat was also found to increase iodine sorption. Two papers have been submitted to the journal Organic Geochemistry to present the findings of this topic:

- Maillant S. and Faure P. Artificial thermal maturation of a natural peat 1. Evolution of the chemical composition, *Organic Geochemistry*, submitted ; and,

- Maillant S. and Faure P. Artificial thermal maturation of a natural peat 2. Control of iodine sorption, *Organic Geochemistry*, submitted.

The final report from the project should be made available mid-year and will be distributed for review prior to finalisation. Overall the collaborative research undertaken was considered very beneficial and it is therefore hoped that similar co-funded projects could be initiated to address further issues.

2.5 Sensitivity analysis of non-human biota assessment parameters

Towards the end of 2007, a proposal was distributed for consideration by the BIOPROTA sponsoring committee for a project to conduct a sensitivity analysis of those parameters key to assessing the potential impacts of releases of radioactivity to the environment on non-human biota. Development of the proposal was championed by Ari Ikonen and the project will be undertaken by Enviros Consulting in partnership with Facilia.

A number of organisations responded favourably to the proposal and funding has been pledged by Andra, Posiva, SKB and NRPA. However, the funding pledged was below that required for the full project and therefore the remit is being revised to take account of the availability of funds and comments received on the initial draft of the proposal. An outline of the current proposal was presented by Carol Robinson.

Preliminary studies of the impacts from deep geological repositories have been undertaken previously for both Posiva and NDA (RWMD). From these assessments it is evident that there are a number of uncertainties associated with assessment parameters and more detailed consideration of the sensitivities and data gaps inherent in assessments would be worthwhile. The objective of the project is therefore to undertake a sensitivity analysis using the most comprehensive method currently available – the ERICA Assessment Tool (AT), developed as a result of two EC funded projects (FASSET/ERICA). The study will focus on those radionuclides most applicable to long-term assessments for deep geological waste disposal facilities.

A number of tasks have been proposed with the aim of evaluating the robustness of the data contained in the assessment database that underlies the ERICA AT for geological repository assessments. Data from the underlying database will be collated and a knowledge quality assessment conducted to determine the robustness of data. This will be followed by a sensitivity study and, once combined, those parameters that influence dose yet lack robustness will be identified. This information can then be used to inform future research requirements to address knowledge gaps. In addition, it is intended that guidance will be provided on the way in which the ERICA AT can be applied to repository release assessments. It is hoped that the output will help improve the level of confidence in non-human biota assessments and prevent the use of overly conservative or pessimistic assumptions.

The output of the project is due to be reported by January 2009 and will be presented during the May 2009 workshop.

Discussions largely focused upon the drivers behind non-human biota assessments. On the whole, the need for such assessments is being driven by developments in environmental legislation. For example, regulatory requirements were identified as a driver for future assessments in France by Elisabeth Leclerc and, similarly, it was noted that regulations in both Finland and England and Wales are being updated leading to greater requirements for such assessments to be undertaken.

Steve Sheppard raised the issue of consistency in approach between chemotoxicological studies (i.e. ecotoxiciology) and that for radioactive substances and noted that a move away from reference organisms to one more consistent with ecotoxicology would be welcome. In response, Carol explained that some aspects are similar. For example, species sensitivity distributions (SSD) were used in deriving the ERICA screening level, which is an approach similar to that used for screening levels for non-radioactive substances. It was also noted that the EC-funded PROTECT project is specifically investigating the extent to which methods that are being developed could be harmonised with ecotoxicological approaches. It was also noted that a draft report has been produced under this project which makes recommendations for screening levels for non-human biota studies, which may be of interest to BIOPROTA participants. Further information on the PROTECT project can be found at www.erica-project.org.

2.6 Assessment of Cl-36 in the biosphere – investigation of behaviour in soils and uptake into crops

In September 2006 a workshop on the behaviour of Cl-36 in the biosphere was held as part of the BIOPROTA programme, hosted by Andra. As a result, a collaborative project was initiated by Andra, JGC, JNFL, NDA (RWMD) and NUMO, to compare and contrast different assessment models. Model approaches from a number of organisations have been contributed, from Andra, EDF, EPRI, IRSN, JGC Corporation, NWMO, NDA (RWMD) and Société de Calcul Mathématique (SCM). The results are being collated into a report by Laura Limer from Quintessa, who outlined the aims of the project and presented the current findings. This report will be finalised in summer 2008.

Chlorine-36 is a dominant radionuclide in post-closure assessments for geological waste repositories. However, there is a lot of uncertainty associated with the behaviour of this radionuclide in the biosphere, particularly in relation to soil accumulation and uptake into plants, both of which can have a large influence on dose predictions. The aim of the model intercomparison was therefore to compare alternative approaches to assess soil accumulation and uptake into plants and to make recommendations concerning dose assessment for long-term post-closure assessment of Cl-36 releases from waste repositories.

Four types of models were employed:

- **Conventional** (e.g. EPRI, BIOMASS, JGC Corporation, SCM (SAMM-TR) and Andra (Aquabios) model approaches) whereby Kd is used to determine the mobile fraction and fixed concentration ratios used to calculate uptake into plants;
- **Specific activity** (e.g. ANDRA (AquaCl36) and NWMO models), which assume Cl-36 reaches equilibrium in some components of the system in the same proportions as stable chlorine and that there is a dynamic treatment of movement between some components;
- **Compartmental model with isotope ratio approach to plant uptake** (e.g SCM (SAMM-IR) and EDF models), which use a complete budget for water and chlorine including losses via percolation in the soil and an isotope ratio approach for plant uptake of chlorine; and,
- **Complex flow & flux** (e.g. IRSN and NDA (RWMD) models) whereby both passive and active uptake by plants is considered with time invariant water content in

different model compartments. Organic chlorine is also taken into account in the NDA (RWMD) model.

Two scenarios were considered – input from irrigation using contaminated well water and a groundwater contamination source. Constant concentrations of both stable chlorine and Cl-36 were assumed. For both scenarios three crops considered (root, leafy green and cereal) and it was assumed that current agronomic methods were employed, based on current model assumptions (e.g. use of fertiliser etc).

The processes considered by the different models varied. For example, some took into account dilution with rainfall, loss through evapotranspiration where others did not. All conventional models employed a triangular distribution for both K_d and soil-plant CR. The approach used for stable chlorine concentrations in plants and soils (and fertiliser if applied) for specific activity models varied between uniform and triangular distributions.

For the irrigation scenario it was assumed that all water enters the root zone (i.e. interception was not considered), but the timing and amount of irrigation was site dependant. For the groundwater scenario it was assumed that the water table was 2m below the surface.

2.6.1 Overview of results

Irrigation Scenario

Complex models were found to predict lower crop concentrations than specific activity models with differences in predictions being statistically significant.

The EPRI model predicted greater uptake into leafy vegetables compared to root crops, but this was the opposite to the Andra AquaCl36 model, which predicted the greatest uptake into plants of all models. Overall there was a two orders of magnitude difference in predictions of uptake into root and leafy vegetables compared with cereal crops.

Results indicated that there is a need for careful consideration of the water balance when modelling Cl-36 uptake into plants.

The influence of model prediction on input parameters was also investigated. Scatter was evident in plots of concentration in cereal crops at harvest in relation to Kd and overall the correlation co-efficient (R^2) was low [however, it was noted that this should be presented in log form]. A greater correlation was found between concentration at harvest and the concentration ratio. Irrigation rate showed the lowest correlation to harvest concentration of the three parameters.

Groundwater Scenario

Not all results have been submitted to date and fewer models overall took part in this scenario. However, currently available results indicate that, in general, crop concentrations are predicted to be lower than those from the irrigation scenario with complex models predicting a high initial uptake into crops that then equilibrates over time.

Conventional models were found to predict much lower Cl-36 uptake into plants than specific activity models, which is considered to be as a result of the influence of stable chlorine.

Further verification of the model results for the groundwater scenario is required.

In discussions, Steve Sheppard suggested that differences seen in the model predictions may arise as a result of the concentration ratio not being in secular equilibrium between stable chlorine and Cl-36. It was also suggested that consideration could be given as to whether or not systems could be better characterised by considering annual data and applying this to long-term assessments. However, overall the different model approaches used were found to predict crop concentrations within a factor of 3.

2.6.2 Cl-36 models for dose assessment

Participants of the chlorine-36 working group were invited to present their models and each of these presentations are outlined below.

JGC Corporation

Kunihiro Nakai presented the JGC Corporation model for Cl-36, which has been developed to assess doses arising from LLW disposal in Japan.

Chlorine-36 is present in activated metal components (e.g. fuel rods), graphite and in spent resin and concentrated liquid waste. The release from activated metal and graphite is thought to be rapid and will be only mildly sorbed in the nearfield. However, in the biosphere, sorption to organic soils (particularly cultivated soils) is considered to be high and accumulation in plants and fish considered likely (e.g. IAEA give a concentration ratio for Cl-36 in fish of 1000).

The JGC model considers the scenario whereby release is to a river or lake that is subsequently used to irrigate crops resulting in soil accumulation and uptake to plants and animals. Parameters included within the model include irrigation rate, concentration ratios (plant and animal), rainfall and irrigation rates and assumptions for cropping rate (variable with crop type), which have been derived from the 2004 statistical handbook of Japan.

Concentration in crops was found to differ according to assumptions of soil Kd in relation to cropping rate and soil-plant concentration ratio. An increase in cropping rate served to reduce long-term predictions of uptake into crops (by around a factor of 10 when in association with a high Kd). Crop concentrations were greatly increased when higher concentration ratios were applied in association with low cropping rates, but did not serve to increase the final crop concentration when high cropping rates and Kd were assumed. Results were not found to be overly sensitive to cropping rate and differences in concentration ratio when small Kd values were applied.

It was therefore concluded that concentration ratio and soil Kd are important parameters that must be consistent and, where large concentration ratios and soil Kd values are employed, cropping rate becomes important.

EDF

Laura Marang presented the EDF model for Cl-36 uptake into crops.

Chlorine-36 is of particular interest to EDF due to the planned graphite waste disposal facility where Cl-36 is predicted to be the main dose contributor.

The EDF model for Cl-36 uptake by plants has been developed over recent years. Initially it was assumed that the plant environment was the same as irrigation water. However, in 2007 this was revised and the model now assumes that the plant environment is equivalent to the water taken up by roots from the soil. It is assumed that the ratio between Cl-36 and stable chlorine remains constant in each model compartment.

Water (and associated Cl-36 and stable chlorine) is taken up from soil into the plant is transpired and this process is governed by several time dependant and spatially dependant processes. Time dependant processes include solar radiation, atmospheric temperature and growth phase of the plant (transpiration rate increases with leaf area index). Spatially independent processes include the distribution of roots within the different soil layers and the chlorine concentrations within these layers.

Inputs of water (and therefore chlorine) considered by the model include irrigation and precipitation. Losses from the system result from soil evaporation and evapotranspiration from the plant. An additional input of chlorine can be from fertiliser application. Chlorine concentrations required therefore include that in fertiliser, rainwater, soil and irrigation water.

The soil compartment is subdivided into topsoil and three subsoil layers and the movement of water between these layers can be by percolation and capillary diffusion (when evapotranspiration rate is greater than combined precipitation and irrigation). Model parameters required for soil layers include depth, Kd, porosity, density and wilting content. For plants, the leaf area index at harvest is a required parameter.

The revision to the models plant environment assumption has resulted in lower and more realistic estimates of Cl-36 uptake into crops. However, the application of this type of model to performance assessments is considered difficult due to the requirement for monthly input data.

SCM-ANDRA

Stéphan Miquel presented the SCM – ANDRA multi-compartment model for which the concentration in soil results from a differential equation that represents advection and diffusion processes. Transfer to the plant can be modelled using a concentration ratio or isotopic ratio approach.

For the irrigation scenario, large variations in Cl-36 concentrations in the rooted top soil were observed due to irrigation during dry summer periods. However, following around 5 years of irrigation practices, steady state is achieved. Overall, periodic variations in soil concentrations are only evident in the upper 60 cm of soil (i.e. the rooted zone).

For the groundwater scenario it is assumed that no irrigation occurs and that precipitation is equal to evapotranspiration. Therefore, the only input is via the aquifer. For this scenario, the time to achieve equilibrium in Cl-36 concentrations was largely influenced by Kd and it is therefore important to ensure accuracy in the selection of this parameter value in order to reduce assessment uncertainty. For scenarios where contamination is from a below ground aquifer, a multi-layer modelling approach is considered necessary.

2.7 Questionnaire responses

In November 2007 a questionnaire was distributed to BIOPROTA sponsoring organisations and to others outside of the organisation with interests in radioecology. 21 widely ranging organisations responded.

A report was produced that summarises the comments received and this was distributed to all respondees for review prior to the workshop. Graham Smith briefly ran through the final collated responses to each question and the recommendations. The intention was to allow participants to take the responses into account during the progress of the workshop.

Particular points of note included:

- The need to update the priority list of radionuclides to take account of a changing focus (e.g. reactor decommissioning);
- Accumulation and dilution processes occurring at the GBIZ and the need to gain a better understanding of the role of particles;
- A rising interest in chemotoxicity and concern regarding rules for demonstrating compliance and in the inconsistency between assessment approaches for radioactive and non-radioactive substances;
- The usefulness of a common database within BIOPROTA was again raised and the suggestion made that this should be simplified to provide available data for which organisations would then be responsible for interpretation and application as appropriate; and,
- Interest in uranium-series radionuclides continues for a number of organisations.

The collation of the responses is to be made available via the BIOPROTA website.

3. BIOSPHERE ASSESSMENT CHALLENGES

Participants were invited to present advances in biosphere programmes since the May 2007 workshop and to highlight any challenges encountered. An overview of the presentations and discussions is provided below.

3.1 The SKB biosphere programme

Progress on the SKB biosphere programme was presented in three stages and each of these is outlined below.

3.1.1 Site description of the surface environment at Forsmark, Sweden

Tobias Lindborg gave an overview of the site characterisation programme for the Forsmark site, which has been in progress since 2001 and is currently in the final phase. The Swedish waste management approach and repository design is based on copper canisters surrounded by bentonite clay located at a depth of around 500 m in bedrock. The repository programme has been running for 30 years with work in 2007 very much focusing on the SR-Can test assessment. Following completion of SR-Can the programme will move toward the actual safety case.

The site description project (SurfaceNet) will be reported in the form of one main report (the site descriptive model) with several supportive/summary documents. The aim is to view the site in a holistic way to ensure that interactions and flows between different ecosystem components are assessed.

Two sites are being considered in Sweden - Forsmark to the north of Stockholm and Laxemar-Simpevarp to the south.

Forsmark is located near to both shoreline and parkland and is in the vicinity of the current low level waste repository. There are no settlements in the area and only sparce human activity. The Forsmark area is very flat with a variation in height above sea level of only 15 to 20 m. The surrounding sea is shallow and shoreline displacement is a major process resulting in new terrestrial habitat. Shoreline displacement and the chemistry of the region have also resulted in a number of unique lakes, which are characterised by a bacterial top layer. There is no evidence of deep groundwater discharge, but there are indications of downward water flow.

The chemistry of the site has been analysed from numerous water samples from soil, lake, boreholes into bedrock, and precipitation. These data are used to determine the source of water (saline, freshwater, groundwater etc). For example, measurements of chlorine over time have been used to track lake evolution whereby chlorine concentrations decline over time as freshwater inputs occur.

Data retrieved from this monitoring programme is being used for hydrological modelling using the MIKE SHE model.

For ecosystem modelling, both biotic and abiotic factors are taken into account. As part of the characterisation programme for ecosystems, vegetation mapping has been undertaken. The overall aim is to be able to map fluxes between different functional units, for example on the basis of carbon budgets.

In lake ecosystems, element distributions have been mapped for different biota (e.g. primary producers, primary and secondary consumers etc) to enable a mass balance approach for inflow and outflow from a system to be employed.

Overall, the site description project has involved 10 to 20 people working full time over a period of 5 years at a cost of around 1 million euros per year. As a result of the programme, a number of lessons have been learnt. For example:

- Time series data are critical for gaining a thorough understanding of the site and this monitoring should be started early as five years is really a minimum for gathering such data;
- The evaluation of data is time consuming and should be conducted by an independent team (one which knows the site, but is not directly involved) to prevent bias;
- It is important that biosphere site description work is conducted in collaboration with those working on the geosphere to ensure a thorough understanding of the GBIZ; and,
- It is easy to suffer from information overload and there is therefore a need to be able to separate out the most important factors.

A range of reports have been produced that describe the main surface system of the Forsmark and Laxemar sites:

- Geological evolution, palaeoclimate and historical development of the Forsmark and Laxemar-Simpevarp areas, Site descriptive modelling, SDM-Site (R-08-19)
- The terrestrial ecosystems at Forsmark and Laxemar, Site descriptive modelling, SDM-Site (R-08-01)
- The limnic ecosystems at Forsmark and Laxemar, Site descriptive modelling, SDM-Site (R-08-02)
- The marine ecosystems at Forsmark and Laxemar, Site descriptive modelling, SDM-Site (R-08-03)
- Description of the regolith at Forsmark, Site descriptive modelling, SDM-Site Forsmark (R-08-04)
- Description of surface hydrology and near-surface hydrogeology at Forsmark, Site descriptive modelling, SDM-Site Forsmark (R-08-08)
- Hydrochemistry of surface water and shallow groundwater, Site descriptive modelling, SDM-Site Forsmark (R-07-55)

Only the latter report is currently available, however the remaining reports will be published by the end of the summer.

3.1.2 Radionuclide transport from rock to surface – handling the GBIZ issue

Sten Berglund presented.

The GBIZ (geosphere biosphere interface zone) can be considered the 'missing link' in the site description process. The basic conceptual model is that groundwater flow enters the biosphere in lower lying regions, but there is a missing link in conceptual models where geosphere models and biosphere models meet and ideally there should be integration between surface and deep rock models. However, this is difficult to achieve.

The upper part of the geosphere is a key component in understanding processes leading to releases to the biosphere and high quality time series data are essential to understanding the site. Such data should include pressure gradients and hydrochemistry.

Land topography governs discharge points at the Laxemar site and also influences flow paths and retention areas. This is not the case at Forsmark, however, where a downward flow of water is evident. Current predicted discharge points are mainly within the sea (based on current shoreline).

At SKB there are a number of overlapping models that overlap such a surface/near surface (e.g. MIKE SHE) and deep rock models (CONNECTFLOW).

Evapotranspiration can have a significant effect on the transport of groundwater. For example, groundwater below a lake during a dry spell was found to flow toward the edges of the lake where transpiration rates were high.

In conceptualising radionuclide transport, data are required for all active compartments. Data such as Kd (derived from field measurements and/or batch sorption experiments), chemical composition of water and solids, organic content, grain size distribution and primary and secondary minerals such as clay and iron hydroxides have therefore been derived. Supportive modelling of retention processes has also been conducted. For the different radionuclides, attempts have been made to identify through modelling what the important factors are that require further consideration and real data.

Reactive transport modelling provides a framework for developing and testing basic transport scenarios and can be used to test the applicability of different approaches such as Kd, retention capacity etc and can also assist in identifying data gaps. However, complex models can also be highly sensitive to uncertain assumptions and input data and can be resource intensive.

For the coming safety assessment work, site data and descriptive models will be used. Large scale models that can take account of variations in space and time will be used, but also more detailed/specific models for plant uptake and discharge points within small areas will be employed.

3.1.3 SKB safety assessment

Progress in the SKB safety assessment was presented by Ulrik Kautsky. From 1 July 2008 the Swedish nuclear inspector (SKI) and the radiation protection agency (SSI) will merge. This has had an impact on funding and the implication on future requirements is still to be determined.

A lot of progress has been made in Sweden over the last 18 months in relation to radioactive waste management programmes. SR-Can was a training safety assessment for HLW disposal in Sweden, which was submitted in November 2006. In addition, the R&D programme (report SKB TR-07-12) was submitted in September

2007 and has been reviewed and approved by the government and a first priority SFR LLW assessment was submitted at the end of April. Work is now underway on SR-Site, which is a site selection assessment.

The SR-Can assessment looked at discharge points at Forsmark and tried to identify what type of ecosystem discharges are predicted to occur, the flow paths between ecosystem compartments and the carbon residence time in different ecosystems. Ecosystem evolution was taken into account by basing predictions on historical evolution.

Dose estimates were based on a carbon budget approach for the foodchain, which helps to avoid issues associated with future consumption habit predictions. Carbon intake requirements were based on a total intake of 110 kg of carbon per person per year and nutrients are the primary constraint on ecosystem productivity. The approach also assists in predicting the size of community that an ecosystem can support, hence the size of the most exposed group. This is considered a sensible approach, but it can be difficult to communicate to non-experts.

The authorities have reviewed SR-Can and were generally positive, however some unresolved issues remain. As a result of some issues raised on SR-Can, further work on landscape modelling has been undertaken and on the linkages between ecosystem compartments. Ecosystem reports will help to describe how models have been developed from site information.

Overall, mires and lake sediments are predicted to retain radionuclides to the greatest extent.

For the LLW SFR, submitted April 30th, some doses were close to the regulatory limit. The main contributory radionuclides were C-14, Cl-36, Se-79, Mo-93, I-129 and Cs-135.

One potential issue identified from current work is that groundwater fauna are being investigated (e.g. stygobionts). New species are being identified and this could cause problems if they are identified at the investigation sites as, unless identified elsewhere, there is concern that they could become listed species.

3.2 The KAERI parameter database

Yongsoo Hwang gave a brief overview of the KAERI programme and introduced an online database that may be of interest to BIOPROTA participants.

Currently there are 20 power plants in operation in Korea and a further 6 are under construction. The Government is supporting the development of an underground laboratory in support of a deep geological repository for spent fuel disposal.

A web based program for the deep disposal system has been developed, which incorporates a quality assured database that is available via the internet. It was suggested that such a system could be used by BIOPROTA in place of the current databook.

The format of the current database was presented and in discussions it was noted that KAERI would be willing to make this version available to the Forum. The system enables direct download of data into MS Excel, however input must be completed manually. The current version is in Korean.

3.3 KBS-3H biosphere analysis: results and reflections

Thomas Hjerpe gave an overview of the Posiva KBS safety studies.

The Swedish-Finnish disposal concept is comprised of two disposal options; one vertical (KBS-3V) and one horizontal (KBS-3H). The main differences are in the technique used to place canisters and that in the horizontal variant the copper canister and surrounding bentonite buffer is enveloped by a perforated stainless steel "supercontainer". From 2002-2007 a joint R&D programme, including various studies relating to long-term safety, was undertaken by Posiva and SKB to determine whether the KBS-3H represented a feasible alternative to the vertical disposal design. The Posiva disposal site (Olkiluoto) was used as the test site on which model studies were performed to identify safety differences resulting from the two disposal options.

The aims of the biosphere analysis were to perform a Posiva state-of-the-art biosphere assessment, including radionuclide transport calculations to derive landscape doses and supplementary dose assessment using two scenarios for deriving safety factors:

- a drinking water well (WELL); and,
- an agricultural well (AgriWELL).

A representative set of calculation cases were used in order to identify limitations. However, the analysis did not comprise a full safety assessment – no formal assessment of doses to the public was performed, but rather to the most exposed individual and a limited assessment of potential impact on non-human biota was undertaken. A real-time development aspect for the landscape was employed for which the current coastal area transitions to terrestrial landscape over the next 8000 years and biosphere objects (mires, forests, lakes, agricultural land etc) have been identified on the basis of the landscape evolution predictions.

Gaseous C-14 releases are treated separately from other radionuclides within the ecosystem models and are based on a specific activity approach.

The main endpoints of the biosphere analysis were the radionuclide inventories in different compartments of biosphere object modules, activity concentrations in different environmental media and annual landscape dose (Sv) to the most exposed individual, based on intake predictions. A conservative approach to landscape dose was used in which it was assumed that a person spent 100% of their time within the biosphere object producing the highest dose and that all water and food consumed were derived from within that same biosphere object.

A number of different release scenarios were considered. For example, the base case assumed an initial small hole in a canister. Other cases considered e.g. the expulsion of contaminated water by gas and the transport of C-14 as volatile gas. Assessments were based on the assumed failure of a single canister only since it can be argued that failure of several canisters at about same location and within a relatively short time has only a marginal likelihood.

For non-human biota, Tier 1 of the ERICA assessment tool was employed. Results indicated doses three orders of magnitude below the screening level.

For human dose assessment, the annual landscape dose to most exposed individual was around 0.1 mSv for the C-14 gas release case, which resulted in a single high

peak in dose. In the other cases I-129 was greatest contributor, followed by Cl-36 and C-14. Small forests near to the shore and short rivers have the potential to provide the greatest doses.

In Finland, the regulatory requirement for the time period over which the safety assessment should be conducted is 'several thousand years', which has been interpreted as 10,000 years for assessment purposes. However, predictions at later time periods have been made to determine whether higher doses could occur past this cut off. Predictions indicate that doses from most cases reduce after about 10,000 years.

3.4 Advances and challenges in Posiva biosphere programme

Ari Ikonen presented.

The current schedule to which Posiva is working is for an outline of documentation for PSAR (preliminary safety assessment report, for the construction license) to be submitted in 2009, with the final input to the PSAR being due in 2011/12. Following this there will be some interim reporting required prior to the final input to the FSAR (final SA report, for the operating license) by 2018.

The documentation is extensive and so it has been organised into a portfolio of folders. Particularly important aspects that run throughout these folders are the GBIZ, human activities in the future and knowledge quality assessment (how well are the models and data used to represent the site known?)

At present surface/near-surface hydrological models are being applied to the future biosphere and the land uplift model is being updated (the elevation model is very important to the overall assessment). Sediment maps and elevation models have been used to make ecosystem and land use forecast predictions.

A second round of biosphere description reporting plus ongoing site monitoring work have begun and, with regard to the radionuclide transport models the landscape modelling concept has been updated.

In order to make a modelling assessment site specific, data are required and local conditions must be taken into account. These data will be subject to expert review and documentation of this review is considered critical to the assessment credibility, traceability and transparency. In addition, a proper sensitivity analysis is important. Water turnover, sorption and biological uptake are considered to be key factors.

An overview of the Posiva web-based database was also presented, which is similar to that of KAERI. The database facilitates expert review – data can be accepted, changes specified or rejected (although final acceptance is by Posiva for assessment use) and dependencies can be stated. References and supporting information can be added. A full data history is kept for all actions. In addition, the database has in-built unit converters to avoid human errors.

There is an issue with confirming the site-appropriateness of some data and it can be laborious to review original papers. However, there is a lot of site data already available, but K_d values are missing (a process has begun to address this gap). There is also the added issue that it can often be difficult to analyse for the most important radionuclides.

A further issue that needs to be addressed is whether or not shoreline forests can uptake radionuclides directly from the releases from the repository/bedrock or indirectly from water bodies as this could change the doses several orders of magnitude.

3.5 Update on NDA RWMD biosphere assessment work

Simon Norris presented an update on the biosphere assessment work undertaken by the NDA RWMD.

In the UK, a Government white paper is expected to be released shortly that will invite communities to volunteer for siting a geological waste repository. Determining factors in decision making would include the ability to investigate different sites and also the transportation of wastes.

As a result, the NDA RWMD is looking to adapt assessment methods to allow investigations of biosphere issues for a range of UK-relevant generic geologies to be undertaken.

Various UK-relevant generic geologies are under consideration as part of this desk study:

1. Hard basement rock in inland areas, which are overlaid with thin surface glacial deposits and peat (e.g. Dounreay).

2. Hard basement rock (within which the repository would be sited) with a sandstone overlay of high permeability within which small aquifers may occur. This is overlain by drift deposits of around 20 m depth within which groundwater can migrate. Radionuclide fluxes are anticipated to emerge within the terrestrial environment such as coastal plain rather than at the coast or offshore. Such a system would be similar to that in the vicinity of Sellafield.

3. Hard basement rocks overlain with low permeability sediment in an area of moderate topography. One permeable formation occurs within the sedimentary sequence referred to as the Jurassic aquifer.

4. Bedded halite in an inland environment, close to a major river.

5. Lower Jurassic shale and mudstones or Triassic mudstones, which underlie a middle Jurassic aquifer that is overlain by Jurassic clays. The area has a low topography and includes an offshore section.

6. Chalk-like (strong sedimentary) host rock that is close to the coast. At depth the chalk is of low permeability, but this increases closer to the surface. The chalk is overlain by low permeability glacial tills and higher permeability sand and gravel formations.

The types of GBIZ considered include shallow wells, both shallow and deep boreholes and natural groundwater discharge and are dependant upon the system in question. Similarly, modelling requirements will differ as will the key exposure pathways for each environment:

Environment 1: Natural discharge and shallow wells

Environment 2: Natural discharge and wells into the regional aquifer

Environment 3: Groundwater abstraction from the Jurassic aquifer (if not too saline to be potable)

Environment 4: Radionuclide transport in groundwater to the biosphere interface is not expected to occur

Environment 5: Groundwater abstraction from the Jurassic aquifer (if not too saline to be potable)

Environment 6: Groundwater abstraction from the higher permeability chalk

The Base Case has been defined in earlier NDA work for a generic site, but involves a groundwater discharge area of 1×10^7 m^2 and an aquifer flow rate of 3×10^5 m^3 per annum. Other cases have been considered, which vary according the groundwater discharge area and aquifer flow rate. For the base case, results indicate that a greater proportion of dose results from a well source compared with groundwater (for example, 95% of dose would arise from the well pathway in the case of C-14).

For the well scenario, the dose implications of changes in consumption parameters have been investigated by inclusion or omission of ingestion pathways such as fish, animal products and drinking water. The full analysis and results are presented in Thorne M C. Biosphere Assessment Studies: Biosphere Calculations for Different Geological Contexts. QRS-1378E-1, Version 1.0, March 2008.

One particular difference was noted in the UK results compared to those of Andra in that Ag-108m has been identified by Andra as being important due to large transfer factors. However, this is not the case in the UK where dose for this radionuclide is dominated by external dose pathways.

An investigation of the implications of the use of the revised EMRAS TRS364 data in a UK context has also been conducted. The revised TRS-364 document will contain updated data for parameters such as Kd, concentration ratios for plants and fish and transfer factors to animal produce. The comparison is reported in Walke R C. NDA RWMD Biosphere Assessment Studies FY2007-2008: Implications of EMRAS Recommendations for NDA RWMD Spreadsheet Calculations, QRS-1378E-TN5, Version 1.0, March 2008[1].

Particular differences were noted for some radionuclides:

- The dose from Cl-36 decreases by 40% due to the introduction of soil sorption and a reduction in soil-to-plant uptake;
- Nb-94 dose increases by a factor of 2.4 due to increased soil sorption (external irradiation dominates exposures);
- Cs-137 dose increased by a factor of 2.4 due to an increase in the concentration ratio for freshwater fish, which is a dominant exposure pathway for this radionuclide;

1 This report will be published following the publication of the IAEA TRS-364 TECDOC and may be updated should the TECDOC necessitate this.

- Dose from Pb-210 falls by 18% as a result of reductions in both soil sorption and freshwater fish concentration ratios;
- Dose from Ra-226 falls by 46% due to a decrease in Kd and a decrease in the contribution from its long-lived daughter Pb-210; and,
- U-233 dose increases by 19% due to an increased contribution from Th-229 via fish for the groundwater pathway, which results from a lower soil Kd.

3.6 Modelling the soil to plant uptake of Ra-226 and progeny (within the U decay series)

Mark Willans presented an idea for a future task on the modelling of the U-238 decay chain for consideration within the forum, which is based on discussions held at the May 2007 workshop. It was proposed that the initial focus would be on the soil to plant transfer system, which is relevant both to land remediation and to geological disposal assessments that deal with uranium.

A proposal has been developed and discussed with Mike Thorne. The project would focus primarily on the lower part of the decay chain (Ra-226 through to Po-210) which often makes a significant contribution to the radiological impacts of geological disposal of radioactive wastes at times long after closure. In such assessments, the in-growth of Rn-222 (radon gas) from Ra-226 tends not to be considered due to its relatively short half-life of 3.8 days. Ra-226 is strongly retained in soils, either being bound to soil solids, or in some cases, being co-precipitated with other alkaline earth elements such as barium.

Within soils, despite its short half-life, radon as a gas can disperse via soil air spaces and can be lost from the surface of the soil where it can be taken up into plant foliage. Therefore, the in-growth of progeny from radon, such as Pb-210 and Po-210, could be more widely distributed within the soil and plant system than would otherwise be predicted if radon in-growth is not explicitly considered. The distribution of Pb-210 and Po-210 in soils and plants as influenced by radon is therefore worthy of investigation in order to examine whether there are any significant radiological implications of not including radon in the uranium series decay chain in dose assessments.

A conceptual model would be developed that would allow for Ra-226 inputs to the soil/plant system from groundwater and irrigation sources. It would include radon in-growth and subsequent decay to Pb-210 and Po-210 (at dispersed locations) and key soil/plant transport processes (as influenced by these radionuclides), including root uptake.

This would involve:

- Development of an overall conceptual model;
- Literature research to identify appropriate papers upon which a numerical model could be developed; and,
- Development of a prototype model within the Model-maker tool.

The proposal is still in the early stages of conceptualisation and can therefore be further developed. Suggestions on approach and scope are invited.

3.7 Iodine transfer factors from stable element analysis

Steve Sheppard presented some new data for iodine transfer factors on the basis of stable element analysis.

Improved analytical techniques have recently been developed in the US and in Germany that make iodine analysis more feasible than the previously available (and expensive) methods such as accelerator and Parr bomb analysis.

For the purposes of the study presented, the German method was employed, which has a detection limit 200 times greater than that of previous methods. In 2006, samples of meat, egg, plant and soil (from both inland (iodine deficient) and coastal sites) samples were analysed. There was good agreement amongst replicate samples and for reference materials.

In 2007 a further sampling programme was undertaken of fish and game at various locations in Ontario close to the LLW repository in the vicinity of Lake Heron, and both the Chalk river and the ECOMatters laboratories. The aim being to generate data relevant to a hunter-gatherer scenario.

An unexpected (and as yet unexplained) correlation was observed between iodine and caesium concentrations in fish sampled from freshwater lakes. A total of 21 fish (pike, small-mouthed bass and walleye) samples have been analysed for which an order of magnitude difference in concentration ratios was observed. Overall, concentration ratios for whole fish were greater than for fillet samples. There was no significant difference between the different species analysed.

Differences between data derived from the 2007 study and that derived previously were presented. In the case of fish, the concentration ratio rose from 6 to 46 L/kg, for birds the transfer factor decreased slightly from 7.5 to 1.1 d/kg, the plant to soil CR (derived from blueberries) remained similar at 0.0039 compared with 0.005 and the sediment/water Kd increased substantially from a range of 4.4-440 to 1200 L/kg.

Measurements of uranium and selenium were also made and compared with previous results. A reasonable agreement with previous data was obtained for the sediment/water Kd and plant/soil concentration ratio in the case of uranium for which the most recent survey provided results of 6600 L/kg and 0.0013, respectively. More varied data were obtained for fish concentration ratios (23 L/kg in 2007 compared with 3 L/kg) and bird and animal transfer factors (2007 data of 0.0052 and 0.009 d/kg compared with 1.2 and 0.0004 d/kg, respectively).

The 2007 survey provided selenium Kd data of 110 L/kg for soil and 50 L/kg for sediment, concentration ratios of 0.24 for plants in relation to soil and 10 L/kg for fish and a transfer factor of 0.16 d/kg for animals (based on wild deer samples).

It is intended that further sampling and analysis will take place in 2008 with a focus on agricultural farms (producing milk, eggs and meat). Five farms for each produce will be sampled with two sampling periods throughout the year. Farms from coastal and mid-continent areas will be selected. In addition, it is intended that some paired garden and field crops (root, leafy vegetables etc) will be analysed to enable plant to plant comparison in the same setting, but under different agricultural practice conditions.

3.8 Joint Project in Greenland to study the periglacial biosphere

Jani Helin presented a joint Posiva/SKB led research project to study a periglacial environment in the west of Greenland. There are four sub-projects, three of which involve ice sheet hydrology with geological and hydrological considerations (including groundwater circulation and chemistry under the ice (and potentially around a future repository)). The fourth sub-project (on which the presentation was focused) involves the periglacial biosphere environment on a transect from the ice margin to the coast. The project will run from 2008 to 2011 and will aim to meet the following objectives:

- increase understanding of the long-term development of the surface environment and of periglacial areas surrounding an ice sheet;
- develop analogues between present conditions and future Scandinavian environments; and,
- conduct radionuclide transport modelling and dose evaluation in periglacial environments.

The overall aim is therefore to provide a 'Periglacial biosphere description' and to identify implications for radionuclide transport modeling and dose evaluation.

Within this sub-project, a number of research interests have been proposed including:

- Vegetation mapping;
- Productivity respiration;
- Surface water discharge and dilution; and,
- Climate reconstruction.

Other interests are invited.

The workplan at present involves:

- Collection of background information and development of a detailed project plan in 2008. A literature review began in April and a field excursion is planned in August. A workshop to finalise the project plan for 2009-2011 will be held in November.
- In 2009 an intensive field work and analysis programme will begin with some initial reporting.
- By 2011 it is intended that the periglacial biosphere description will be completed.

Other participants are invited, and anyone interested should contact Jani directly. Contact details can be obtained from the BIOPROTA technical secretariat.

3.9 Overview of Current Status of Japanese Program and NUMO's Activity

Keiichiro Wakasugi presented.

The Japanese siting procedure for a geological waste repository involves three stages:

- Literature searches for volunteer sites and their surroundings;
- Preliminary investigation (e.g. surface-based sampling such as boreholes plus geophysical prospecting); and finally,
- Detailed surface investigations and tests within an underground research facility.

Once these stages have been completed a decision on the final disposal site can be made.

In January 2007, Toyo town applied as a candidate site and literature surveys began. However, in April the Government approved the withdrawal of the town as a candidate site following a change in Mayor.

Following this, the disposal programme has been further promoted through nationwide public relations exercises and greater stakeholder engagement. In addition, amendments were made to the Final Disposal Act, which altered the financing scheme for TRU waste (LLW arising from spent fuel reprocessing and mixed oxide fuel (MOX) fabrication facilities). TRU waste has now been re-categorised as ILW due to the concentrations of some radionuclides within the waste stream and will therefore be disposed of to a deep geological facility opposed to surface disposal.

NUMO is the organisation responsible for the disposal of all HLW and is also jointly responsible with JNFL for the disposal of TRU. JNFL are responsible for the disposal of all other LLW in Japan.

The current status of NUMO biosphere assessments was presented.

In previous assessments it was assumed that a repository would be sited inland in an unchanging environment. However, this has been revised to include coastal sites and there is therefore a need to build up a technical basis for the repository concept in coastal areas, taking into account sea level change.

Sea level change brings new challenges in that the processes involved in radionuclide transport will vary between coastal and inland scenarios. Inland, transport is largely a result of advection. Radionuclides enter fracture zones in the host rock where transport can be retarded by sorption in the rock matrix. However, transport of radionuclides under the sea bed is largely by diffusion and any changes in the salinity of the groundwater will affect transport parameters such as Kd and diffusion coefficients.

As a result of these differences, the conventional 1-dimensional transport model cannot be applied to coastal sites and a new 2-dimensional transport model has therefore been developed. The model takes into account the interaction between fresh and saline waters, the different modes of radionuclide transport that occur both under and adjacent to the sea and accumulation in coastal bed sediment.

The model deals with groundwater flow direction and velocity, groundwater chemistry and the geophere biosphere interface as a function of time.

In discussions the issue of seabed disposal was raised as this is has been discussed in relation to the Swedish LLW repository for which suggestions have been made to

locate below the sea. However, seabed disposal is not considered to be an issue in Japan. The simplicity of the modelling approach was also queried, but at this stage there is no specific site and therefore the level of modelling is considered appropriate for a generic situation.

3.10 Research status in France on geological disposal of high-level and long-lived radioactive waste

Elisabeth Leclerc presented the current status of research conducted by Andra relating to the geological disposal of radioactive waste in France.

The milestones in relation to a HLW repository in France are as follows:

- 2012 – submission of report providing the basis for public debate (recommended by Andra to be held in 2013);
- 2014 – submission of license application (including environmental impact assessment);
- 2015 – evaluation of license application for repository construction;
- 2017 – start of construction;
- 2025 – first waste emplaced;

The repository will be constructed in sedimentary rock within a stable basin. Work began in 2005 on a defined transposition zone of around 250 km^2, which will be reduced to a 30 km^2 interest zone from 2009.

The repository design is based on a single level layout in the middle of the host rock that can be accessed by four grouped shafts. A number of distinct zones will be available for waste emplacement to ensure limited interactions between waste types. The modular format also allows gradual construction and modular management.

Andra are actively involved in a research programme, for which iodine, chlorine and selenium are the elements of greatest interest, largely due to the fact that 80% of dose is predicted to arise from consumption of radioisotopes of these elements in drinking water, for which there are a number of uncertainties. Studies have been initiated, in collaboration with IRSN, to investigate foliar transfer of these elements and on selenate speciation in soils, through in situ experiments, and model development for selenium behaviour in soils. In addition, in situ studies of stable concentrations and speciation in environmental samples from forest and agriculture in the vicinity of the site are underway and a specimen bank for foodchain samples is being developed.

A surface environment characterisation programme has also begun. The site is located inland and is primarily used for agriculture (both open fields and grassland, with some forest areas). Some protected species are located within the area.

The application to construct the repository will require a detailed description of the installation and its operation and a very detailed environmental impact assessment (inclusive of data from the site characterisation programme). In addition, a preliminary safety report will be included that takes account of climate change and the procedures

envisioned for the management, closure and monitoring of the repository and for the ongoing environmental monitoring programme (anticipated duration of 100 years).

In addition to work on the geological repository for HLW, Andra are also involved in a large graphite disposal project for which a legal deadline of 2013 is to be met. However, there are considerable issues in meeting this deadline, particularly considering that no site has yet been identified.

3.11 Presentation of CESAMM – Methods and Projects

Veronica Gyuricza presented research that is being conducted on soil fungi, a diverse group of organisms that are often associated with plants. Mycorrhizal fungi can constitute 20 to 30% of the soil biomass and a single gram of soil can contain several meters of hyphae.

A number of experimental studies are being undertaken to look at the association between plant roots and fungi and the role that mycorrhizal fungi play in the uptake of elements (e.g. N, C, U and Cs) by plants. Root organ cultures have been established using bi-compartmental Petri discs whereby root to shoot translocation and gas exchange can be measured. The experimental set up enables successful plant growth with up to 200 plant replicates being run at any one time.

A number of publications are available relating to radionuclides of interest to the BIOPROTA forum:

- Effect of potassium and phosphorus on the transport of radiocesium by arbuscular mycorrhizal fungi. **Gyuricza et al.** *Journal of Environmental Radioactivity, 2008*;
- Role and influence of mycorrhizal fungi on radiocesium accumulation by plants **Dupré de Boulois et al.** *Journal of Environmental Radioactivity, 2008*;
- Transport of radiocaesium by arbuscular mycorrhizal fungi to *Medicago truncatula* under in vitro conditions *Environmental Microbiology, 2006*;
- Contribution of extraradical mycelium and roots to radiocaesium uptake and translocation by arbuscular mycorrhizal carrot roots under root organ culture conditions *Environmental Pollution, 2005*;
- Extraradical mycelium of the mycorrhizal fungus *Glomus lamellosum* can take up, accumulate and translocate radiocesium under root organ culture conditions **Declerck et al.** *Environmental Microbiology, 2003*;
- Impact of arbuscular mycorrhizal fungi on uranium accumulation by plants **Dupré de Boulois et al.** *Journal of Environmental Radioactivity, 2008*; and,
- Use of mycorrhizal fungi for the phytostabilisation of radio-contamined environments (European project MYRRH): Overview on the scientific achievements *Radioprotection, 2005*.

Ongoing work includes investigation of the role of potassium on the photostabilisation and extraction of Cs-134 by mycorrhizal plants; the dynamics of Cs-134 uptake; and the transfer of contaminants to fungi following foliar contamination.

There was considerable interest in the research technique, particularly with regard to the possibility of studies on the different chemical forms of selenium and uptake into plants in relation to the presence of fungi.

3.12 Critical issues for dose calculation in safety assessments of radioactive waste repositories: Some conclusions from the Climb modelling project

Graham Smith presented on behalf of Shulan Xu and Björn Dverstorp from SSI who were unable to attend the workshop.

SSI has undertaken a regulatory review of work presented by SKB for the Swedish deep geological radioactive waste repository. A report has been produced in support of this review that details independent modelling using CLIMB (Rapport 2008:08 – independent consequence calculations in support of regulatory review of SR-Can Safety Assessment).

The model results verify that discharge points are predominantly located in low areas of catchments where the layers of quaternary deposits often are relatively deep (e.g. streams, wetlands and lakes) and are primarily associated with deformation zones.

The CLIMB transport model results indicated that calculated dose is inversely proportional to the size of the contamination area, for which areas assumed within the SR-Can report are substantially higher than those predicted using CLIMB and therefore SSI predicted higher doses. Results also indicate that the accumulation of radionuclides in Quaternary deposits is a process that contributes significantly to dose as a result of the predicted land uplift.

In reviewing the SR-Can submission, the role of SSI was very much to evaluate the level of assessment and identify where assumptions are too pessimistic or not conservative enough, but also to support developments that would help simplify review of the final safety assessment. Overall, there were few questions arising from review of the submission. However, it was considered that further justification of the SKB models was required through supportive information derived from the site characterisation programme.

4. TOPICS FOR FURTHER WORK

A summary of the topics of interest to BIOPROTA sponsoring organisations and the wider radioecology community as identified from review of questionnaire responses was provided by Carol Robinson. From the summary, a list of possible areas for further work was drawn together (and enhanced through subsequent discussions and points arising from presentations during the workshop) and participants were asked to identify those subjects that would be of most interest to their organisations. Where subjects were of interest to multiple organisations, champions were invited to ensure that projects are developed throughout the 2008/09 membership period. Tabulated interest areas and responsibilities are provided below. Additional project support is invited and anyone interested in supporting tasks should contact the project champions and/or the Technical Secretariat as appropriate. Contact details for project champions can be obtained from the BIOPROTA Technical Secretariat.

In some cases, no champion was identified, even though the issues had been raised as significant. This reflects that not every potentially interested organisation had been able to attend the workshop. If readers of this report wish to express interest, please contact the Technical Secretariat.

Topics for further work	Comments/Further detail	Registered interest/ Champion (C)
International review of regulatory requirements as they impact on PA approaches.	Compilation of international regulations and guidance to identify commonality and differences. Identified as a potential option to take forward	Elisabeth Leclerc (C if other interest received)
Selenium Working Group.	Literature searches & review to capture the information already available, including than from research into stable selenium	Matthias Brennwald (C) Nagra, CIEMAT, Andra, SKB, NDA and Posiva interested
Learn from, as well as inform, monitoring and assessment experience of contaminated nuclear legacy sites. This could include contributions to optimisation assessments and environmental decision-making.	Identification of what is monitored and how at legacy sites so as to inform site restoration plans. Application to near surface disposal and contaminated land management.	No champion defined.
Time-frame over which particular processes can be said to be in equilibrium (or steady state).	Application within assessment models (including use of continuous or step functions). This was considered an issue for general consideration rather than a topic in its own right.	No champion defined.

Topics for further work	Comments/Further detail	Registered interest/ Champion (C)
Application of biosphere assessment tools to the determination of environmental concentrations of repository derived radionuclides as alternative indicators of safety.	Definition of the modelling approach required, –for example, what volumetric and temporal averaging procedures are necessary, for direct application of radionuclide fluxes and concentration data as alternative safety indicators. No identified task at present.	No champion defined.
Development of an exercise on C-14 dose model inter-comparison, similar in objectives and scope to that in progress for Cl-36.	Applicable to all types of repository and from routine discharges. More complex task than Cl-36, but with different types of involvement such as inter-comparison or peer review as appropriate, taking into account EMRAS experience & scenarios from routine releases.	Champion to be confirmed CIEMAT, JNFL, EDF, NDA, Nexia, Nagra, and Andra expressed interest Posiva and SKB offer models and data
Completion of a study of multi-stressor (environmental) effects as may be relevant in radioactive waste management.	Definition of issue and capability to deal with it questioned.	No champion identified
Development of conceptual soil/plant process model for lower part of uranium decay series (Ra-226 and progeny of Rn-222, Pb-210 and Po-210) with irrigation and groundwater inputs of Ra-226; also implementation of a prototype model using appropriate software..	See Section 3.6. A recent publication was identified as relevant: S Sheppard - Ra and daughters in different locations and crops (JER Vol. 99, 6).	Mark Willans (C) SKB, Andra, Nagra, NDA and CIEMAT interested CIEMAT can offer data resulting from mine waste Posiva would like to be kept informed
Development of a model intercomparison exercise featuring progeny of uranium decay series such as Th-230 – Ra-226 – Pb-210 – Po-210 and endpoints of time dependent environmental concentrations and dose..	Model intercomparison could explore the implications of including or excluding radon in the decay chain, particularly the radionuclide dependent transport processes involved. It could also explore the effect of explicitly including Po-210 as a decay chain member or assuming that it is in secular equilibrium with Pb-210.	
Illustrative calculation of U release impacts on humans and non-human biota, using repository PA assessment methods, but calculating radiation and non-radiation impacts for comparison with protection criteria applied in each context.	This would be partly to support NORM and TENORM management and partly to enable the experts in the separate areas to share information and experience. Focus on U in the environment (not in equilibrium or DU) considering both radiation impacts and toxicity.	CIEMAT interested and may be willing to champion. NDA & Nexia interested.

Topics for further work	Comments/Further detail	Registered interest/ Champion (C)
Consideration of the above suggestion on U and Th series radionuclides in the context of NORM and TENORM waste management, c.f. nuclear fuel cycle waste management.		
Calculation of health impacts from beryllium or other stable element releases, using methods applied in repository PA and health endpoints developed in a radiation protection context.	Potential inclusion of environmental as well as health impacts.	Simon Norris (C) Andra and Nagra interested.
Consideration of low-level (hunter-gatherer) exploitation of environmental resources, especially for potentially sensitive environments, such as the arctic and near-arctic.	Included as a factor in the Greenland study presented by Jani Helin. The study group will review results of Greenland studies for generic application as appropriate.	No action at present and no champion required.
Consideration of the use of analogues, taking account of work already in progress on lanthanides, as analogues for the actinides, and on analogues for Cl-36 and C-14.	The use of man-made analogues such as lanthanides for actinides was raised in questionnaire responses. Also consideration of previous releases of Cl-36 and C-14 for greater understanding of transport. Stable C and Cl useful analogues!	No action at present.
Study of the use of natural radionuclide fluxes from the geosphere to the biosphere, and current day measurements of exposure from the same natural radionuclides in the same area, as analogues for repository derived radionuclide transfers and exposures. Such a study could inform decisions on model assumptions for estimating repository impacts for these radionuclides and/or provide a measure of whether current model assumptions result in gross over- or under-estimates of exposure.	Suggested use of knowledge of radiation exposure arising from natural fluxes as validation of modelling of repository derived fluxes to the biosphere, and to evaluate the extent of conservatism in repository assessments. Identify sources of available knowledge (scale and averaging issues). Future EMRAS WG on Norm – may be issue for consideration – consultation suggested. Information on elemental behaviour available (e.g. SKB). This sort of assessment has been considered in the past and would comprise a complex task.	No champion identified.

Topics for further work	Comments/Further detail	Registered interest/ Champion (C)
Study to compare human intrusion assessments for near-surface disposal and/or contaminated land use.	Comparison of human intrusion assessment methodologies to identify ways in which event and consequences are considered. ASAM interaction possible. NEA also reviewed regulatory aspects (dated). If interest contact MW – then determine whether sufficient interest to take forward.	Nexia interested in relation to shallow disposal. Posiva interested for deep respository. NDA can provide information on UK approach. Andra and Nagra would like to be kept informed.
Targeted experimental and field work, in cooperation with the IUR-UIR and other organisations.	Important to maintain the link between BIOPROTA and IUR (e.g. Yves Thiry). Posiva suggested the use Olkiluoto site for potential field work. Needs task identification definition through desk research, e.g. as planned within the Se-79 working group.	No action at present.
Theme 3 Update (Site Characterisation)	Continuing with update by requesting experience from relevant organisations.	NUMO and Andra interested. SKB happy to contribute. Graham Smith (C) – Task started.
Database continuation	Develop objectives: Possibility to make available in website format. Posiva and KAERI databases are possible models. It is important that the database be administered and maintained by a single organisation. A two stage approach suggested – initial inclusion of data already available (from the BIOPROTA datasheets) followed by a second stage to further advance data availability.	Andra, Posiva, KAERI and SKB interested. Thomas Hjerpe (C) – project plan to be developed with specified objectives for review.
Cl-36 Working Group	Ongoing	Achim Albrecht (C)
Non-human Biota	Ongoing	Ari Ikonen (C) supported by Karen Smith Contributors: Posiva, SKB, Andra and NRPA.
Greenland study	Ongoing. Further contributions invited.	Posiva (Jani Helin - C) and SKB are participants. Contact with NRPA and NWMO/OPG suggested.

5. ADMINISTRATIVE ISSUES

Tobias Lindborg, the Sponsoring Committee chairman, noted that he was happy with the operation of the workshop, including the progress with existing projects and the development of proposals. He hoped that the representatives of the sponsoring organisations agree and he thanked all for their participation and interest. He proposed that the Committee should work further to encourage wider membership and to update the BIOPROTA objectives and strategy, in parallel with the results of the recently completed questionnaire. Accordingly he invited comments and suggestions.

It was also suggested that annual meetings of the sponsoring organisations should be reinstated to take place during the annual workshops. These would be closed meetings to be attended only by representatives of the sponsoring organisations. Tobias will contact sponsors directly to gauge opinion on this suggestion.

The current Forum sponsoring organisations are detailed below for information.

Organisation	Contact
Andra, France	Elisabeth Leclerc
SCK.CEN, Belgium	Geert Olyslaegers
CIEMAT, Spain	Cristina Trueba
EDF, France	Philippe Ciffroy
KAERI, Korea	Yongsoo Hwang
Nagra, Switzerland	Matthias Brennwald
Nexia Solutions, UK	Mark Willans
NRI, Czech Republic	Jiri Landa
NUMO, Japan	Keiichiro Wakasugi
NWMO, Canada	Paul Gierszewski
Posiva, Finland	Ari Ikonen
SSI, Sweden	Bjorn Dverstorp
SKB, Sweden	Ulrik Kautsky
JGC Corporation, Japan	Kunihiro Nakai
NDA (RWMD), UK	Simon Norris
EPRI, USA	John Kessler
NRPA, Norway	Per Strand

5.1 2009 Forum meeting

The next BIOPROTA meeting (BIOPROTA XI) will be held in May 2009. Location and date to be confirmed (possibly 12-14 May 2009 in Sweden (hosted by SKB) or Spain (hosted by CIEMAT)).

APPENDIX A: LIST OF PARTICIPANTS

Name	Organisation
Achim Albrecht	ANDRA, France
Elisabeth Leclerc	ANDRA, France
Danyl Pérez	CIEMAT, Spain
Steve Sheppard	ECOMatters, Canada
Laura Marang	EDF, France
Carol Robinson	Enviros, UK, *BIOPROTA Technical Secretariat*
Karen Smith	Enviros, UK, *BIOPROTA Technical Secretariat*
Graham Smith	GMS Abingdon, UK, *BIOPROTA Technical Secretariat*
Kunihiro Nakai	JGC Corporation, Japan
Yoshihiro Miyauchi	JNFL, Japan
Yongsoo Hwang	KAERI, Korea
Matthias Brennwald	Nagra, Switzerland
Frits van Dorp	Nagra, Switzerland
Simon Norris	NDA (RWMD), UK
Mark Willans	Nexia Solutions, UK
Keiichiro Wakasugi	NUMO, Japan
Natsuko Higuchi	NUMO, Japan
Jani Helin	Posiva, Finland
Ari Ikonen	Posiva, Finland
Thomas Hjerpe	Posiva, Finland
Laura Limer	Quintessa, UK
Ulrik Kautsky	SKB, Sweden
Tobias Lindborg	SKB, Sweden
Sten Berglund	SKB, Sweden
Birgitta Kalnowski	SKB, Sweden
Stéphan Miquel	Société de Calcul Mathématique SA, France
Veronika Gyuricza	University Louvain, Belgium