BIOPROTA

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

Report of the Sixteenth BIOPROTA Workshop

London, UK

19-20 May 2014

Version 2.0, Final
28 October 2014

PREFACE

BIOPROTA is an international collaboration forum which seeks to address key uncertainties in the assessment of environmental and human health impacts in the long term arising from release of radionuclides and other contaminants as a result of radioactive waste management practices. It is understood that there are radio-ecological and other data and information issues that are common to specific assessments required in many countries. The mutual support within a commonly focused project is intended to make more efficient use of skills and resources, and to provide a transparent and traceable basis for the choices of parameter values, as well as for the wider interpretation of information used in assessments. A list of sponsors of BIOPROTA and other information is available at www.bioprota.org

The general objectives of BIOPROTA are to make available the best sources of information to justify modelling assumptions made within radiological and related assessments of radioactive waste management. Particular emphasis is to be placed on key data required for the assessment of long-lived radionuclide migration and accumulation in the biosphere, and the associated radiological impact, following discharge to the environment or release from solid waste disposal facilities. The programme of activities is driven by assessment needs identified from previous and on-going assessment projects. Where common needs are identified within different assessment projects in different countries, a common effort can be applied to finding solutions.

This report describes presentations and discussions held during the sixteenth annual BIOPROTA workshop held from 19-20th May 2014. The workshop was hosted by Radioactive Waste Management Limited (RWM) in London, UK. Technical inputs were provided by a wide range of organisations via presentations and discussions, as described in the report.

The report is presented as working material for information. The content may not be taken to represent the official position of the organisations involved. All material is made available entirely at the user's risk.

Version History

Version 1.0: Draft workshop report prepared by Karen Smith and reviewed by Graham Smith (BIOPROTA Technical Secretariat) based on participant presentations and workshop discussions. Distributed 14 August 2014 to workshop participants for comment.

Version 2.0: Final workshop report prepared by Karen Smith and reviewed by Graham Smith (BIOPROTA Technical Secretariat), taking into account participant comments on the version 1.0 draft report. Distributed 28 October to workshop participants and BIOPROTA member organisations.

CONTENTS

1. INTRODUCTION

The sixteenth BIOPROTA workshop was hosted by Radioactive Waste Management Limited (RWM) in London, UK from 19-20 May 2014. The support of RWM in the organisation and hosting of the workshop is gratefully acknowledged.

The workshop was opened by Ray Kowe (RWM) with an overview of membership and progress with BIOPROTA activities since the last annual workshop in Slovenia in May 2013.

BIOPROTA participation is aimed at national authorities, agencies and other organisations, including technical support organisations and independent research institutions, with responsibilities and interests related to achieving safe and acceptable radioactive waste management. The member organisations at the time of the meeting included:

- ANDRA, France
- ARAO, Slovenia
- AREVA, France
- BFS, Germany
- CIEMAT, Spain
- EDF, France
- ENSI, Switzerland
- EPRI, USA
- FANC, Belgium
- IRSN, France
- JGC, Japan
- KAERI, Korea
- LLWR, UK
- NAGRA, Switzerland
- RWM, UK
- NRPA, Norway
- NUMO, Japan
- NWMO, Canada
- POSIVA, Finland
- SCK-CEN, Belgium
- SKB, Sweden
- SSM, Sweden

There are additionally two academic members; Oregon State University, USA, and the University of Life Sciences, Norway.

Since the last annual workshop, work programme progress has included:

- Publication by SSM of a C-14 workshop report that was held in 2013 and a further workshop being held in Aix-en-Provence, hosted by IRSN, on ‘Data, Ecosystems and Dose Assessment’ at which scope for model testing was identified for both terrestrial and aquatic environments.
- Publication of a workshop report on Scientific Basis for Long-term Radiological and Hazardous Waste Disposal Assessments, a workshop that was held in Slovenia, hosted by ARAO, in the days following the annual workshop. A follow on workshop is planned focussing on comparison of assessments for radioactive and hazardous waste disposal. It is anticipated the workshop will be held in early 2015.

- Development of a final report on An Exploration of Approaches to Representing the Geosphere-Biosphere Interface in Assessment Models, which included two project workshops, one hosted by RWMD in London and a second hosted by Andra in France. A JER publication on the subject has also been published and a presentation made during the ICOBTE 2013 conference.

- The SPACE project on temporal and spatial averaging in waste disposal dose assessment continues in progress, taking account of activities being undertaken by the MODARIA biota working groups and the recent guidance on protection of the environment in ICRP Publication 124.

The annual workshop is aimed at providing an opportunity for participants to consider further research and assessment priorities for waste management assessments and to discuss next steps in projects and proposals to address those priorities.

1.1 OBJECTIVES AND SCOPE OF THE WORKSHOP

The objectives of the workshop were:

- to briefly update interested parties on progress since the last meeting in May 2013 on the various activities and projects supported through BIOPROTA;

- to provide an informal forum for continuing exchange of information and discussion about biosphere topics of interest; and

- to identify common scientific issues relating to the assessment and analysis of safety for radioactive waste disposal facilities, upon which collaborative tasks may be developed.

1.2 PARTICIPATION

The workshop, hosted by Radioactive Waste Management (RWM) in London, UK and was attended by 27 participants from 10 countries, representing a range of operators, regulators, researchers and technical support organisations. Participants are listed in Appendix A.

1.3 REPORT STRUCTURE

Section 2 of this report summarises the presentations made by participants. Section 3 then provides an overview of progress with BIOPROTA activities since May 2013 and an overview of parallel international work programmes is presented in section 4. Future work programme suggestions and forum arrangements in 2014-15 are introduced in section 5.

2. PARTICIPANT PRESENTATIONS

Summaries of each of the presentations made during the course of the workshop are presented below, including key discussion points.

2.1 OVERVIEW OF THE RWM BIOSPHERE RESEARCH PROGRAMME

Ray Kowe Presented.

The UK siting process to identify potential sites where a geological disposal facility (GDF) could be located was set out in the 2008 White Paper and operated for five years. A number of communities engaged with the process, and participated in its early stages. However, the discussions between the interested parties did not progress so that by February 2013 there were no longer any communities actively involved in the siting process. Since then, the UK Government has carried out a review of the process, including a Call for Evidence and formal public consultation, which took place in 2013. In July 2014 it issued a revised policy framework which updates and replaces (in England and Northern Ireland) the 2008 White Paper. The new policy retains the voluntarist approach, based on working with communities that are willing to participate in the process to identify potential sites.

In the absence of a site, the representation of the biosphere is kept as simple as possible. A catchment area is considered within which a potentially exposed group (PEG) is located. Both groundwater upwelling and extraction from wells for crop irrigation and drinking water are considered and the geosphere-biosphere interface is of particular interest. A sequence of different climate states is considered and RWM is participating in the IAEA MODARIA programme on this subject (working group 6).

Recently, a coastal model has been developed to complement the terrestrial model. The development allows processes within an estuary to be considered or, alternatively, the estuary can be closed off to allow a beach area to be incorporated in the assessment. Input to an estuarine or coastal system can be direct from transport from a near-surface aquifer or from transport from the terrestrial system via surface water transport pathways. The model was based on a review of estuaries around the UK to allow a UK-generic model to be developed in terms of estuarine processes and geology. The model is implemented within the GoldSim modelling platform and documentation for the model is available in the open literature.

A particular focus of the RWM research programme has been on C-14 modelling and assessment. A field and laboratory research programme has been undertaken, on behalf of RWM, by the University of Nottingham over the last 3 years. Reports of the programme are currently in production.

The RWM biosphere status report is also being updated. Work on the updated report began in March 2014 and is due to complete in 2015. The marine model will also be further developed to allow consideration of different climate states, allowing it to be run in tandem with the terrestrial model. It was noted that there is an EPRS funded programme, ARCoES, looking at the effects of climate change on estuaries. Information is available from www.arcc-network.org.uk.

RWM is also providing support to the TREE research programme (see section 4.5) and has also helped in the organisation of a Geodisposal conference that took place in Manchester in June.

2.2 SKB: RESULTS FROM PRESENT WORK AND FUTURE CHALLENGES

Eva Andersson presented on work being undertaken on the SR-PSU safety assessment for an extension to the Swedish low and intermediate level waste repository, SFR. Altogether, 3 repositories

are planned; an application for the construction of a high level waste facility, at a depth of 500 m, was submitted in 2011. SFR is currently operational with a disposal depth of around 60 m, but for which an extension to the facility is being sought. A third assessment for a long-lived intermediate level waste repository (SFL) is due to begin in the autumn; no site has yet been selected for this facility.

The SR-PSU assessment includes a number of model developments from the previous assessments performed for the SFR repository, including use of a coupled near-field to biosphere model. The way in which C-14 is modelled has also been revised and the landscape model further developed. The SFR facility is located on the coast (the disposal area is currently under the Baltic Sea). Over time, as a result of continued post-glacial land uplift, the facility will be located under the terrestrial environment. As such there is a need to consider how radionuclides will behave in the different ecosystems in the developing landscape.

Geohydrological models have been applied to identify potential release areas at the surface for radionuclides from the repository. A radionuclide transport model allows radionuclide transport within the biosphere to be evaluated following their entry in groundwater and movement through the regolith. A new atmospheric model has been developed for C-14 that takes account of degassing; the C-14 model has been validated against C-12 data. A finer resolution of regolith layers has also been incorporated into the SR-PSU models that take account of organic matter in sediments, which enables modelling of accumulation of radionuclides with no or low Kd such as C-14 and Cl-36.

The handling of the most exposed group has also been updated in the assessment. An exposure pathway analysis was performed where 17 exposure pathways were identified and mapped to one or more exposed groups. Four different exposed groups were identified and considered credible to use as bounding cases to cover all identified exposure pathways. The potentially most exposed groups are based on historical and present societies and are:

- Hunter-gatherer in a natural ecosystem;
- Farmer draining a mire for agricultural purposes;
- Infield outland farmer in which inland farming of crops are dependent on nutrients from wetland for haymaking (outland);
- A garden plot household that is self-sustained in regards to vegetables and root crop and that irrigate the crop with waster extracted from a well that may contain water originating from the repository.

Although the main assessment was performed with a coupled geosphere-biosphere model, also unit releases were used in the biosphere part of the model in order to evaluate the model and to check for reasonableness and to compare with the output from the previous assessment model through landscape dose factors.

The SR-PSU assessment is being performed for a time window of 100,000 years and therefore considers different climate states. Preliminary results indicate that doses are all below the required dose limits. The highest dose results from the drainage of a mire that is subsequently used for agriculture or from the irrigation and fertilisation of a garden plot as compared with other land uses. For long-lived radionuclides (half-life longer than 1,000 years) the major exposure routes were ingestion of food or well water. For shorter-lived radionuclides, ingestion of water from a well was always the dominant exposure pathway.

Landscape dose factors were lowest for the marine stage of landscape evolution and greatest during the land phase when biosphere objects can be cultivated. Time is therefore an important consideration in terms of dose calculations.

A detailed site characterisation programme has been undertaken for the area and, hence, there are substantial data sets to support the assessment. Since the previous assessment for SFR, models have been updated with site data for Kd and CR.

New site data on digital elevation modelling and regolith depths have been included and the delineation of biosphere objects has been revisited since the last assessment. Different delineation of biosphere objects (areas where radionuclides may reach the surface ecosystem) has been studied in the assessment. The results of the object delineation study are currently being reported; there is confidence in how the biosphere objects are represented in terms of object delineation. The release location for radionuclides and position in the landscape can be very important in an assessment, but once an area has been identified, object delineation does not have a large impact.

There is still further work to be undertaken at SKB. Review comments on the SR-Site assessment from the regulator continue to be addressed as they arise and the final SR-PSU assessment is due to be submitted in September. The SFL assessment will then begin. Further research is also due to be undertaken that may be valuable for long term assessments. Key radionuclides for assessments have been identified as Mo-93 and Cl-36 with the former being of particular concern due to redox behaviour and a greater data basis is required on the behaviour of these radionuclides in the biosphere. For example, it is likely that, due to lack of data on Mo-93, the assessment is quite conservative for this radionuclide leading to its relative importance in the dose assessment.

Further work is also required to address remaining conservatisms in C-14 assessment.

Further research plans by SKB include:

- addressing organic matter fluxes in the biosphere and consequences for radionuclides transport; and,
- investigating the effect of calcite leaching on Kd and radionuclide behaviour over time (calcite leaching leading to changes in pH and sorption processes).

2.3 POSIVA BIOSPHERE ASSESSMENT: MAIN UNCERTAINTIES AND HOW TO ADDRESS THEM

Kirsi Riekki presented.

The Posiva license submission for the construction of a geological disposal facility for spent nuclear fuel has been submitted to the Finnish regulator. The biosphere assessment, BSA-2012, undertaken in support of the license submission, consists of a report portfolio. There are three main reports (Biosphere Description, Biosphere Assessment and Data Basis) that are supported by four assessment reports that are themselves supported by a series of working reports.

A number of different models have been applied in the assessment, including terrain and ecosystem, climate, surface hydrological and human and biota dose models. Site data obtained from the Olkiluoto site itself and from a reference area have been used to underpin each of the models applied. The biosphere has been considered in terms of several biotopes; there are no lake biotopes currently present around Olkiluoto Island and reference lakes have therefore been identified and studied. Lakes are considered likely discharge areas so reference lakes that are similar to the type likely to be formed

in the future around Olkiluoto were identified. Reference mires have also been identified and studied for similar reasons.

Since submission of the license application, work has begun on the next stage of assessment that is due to be submitted in 2020. This will address key uncertainties in the BSA-2012 assessment.

There are two key uncertainties in the BSA-2012 assessment:

- The radioactivity inventory source term; and
- Location of the discharge.

Work is currently being undertaken to address uncertainty around the radionuclide inventory source term by identifying a conservative list of radionuclides that should be taken into account in the next stage of assessment. Radionuclides are being identified by screening all possible radionuclides according to their transport time through the rock matrix. The final list of radionuclides is selected by combining geological transport time and dose contribution in the surface environment.

Discharge locations have been identified from a statistical approach involving bedrock models and the bedrock fracture network. This may be revised for future iterations of the assessment with real bedrock fractures being used as discharge locations. A decision on the final approach to be employed remains to be taken.

Overall, biosphere uncertainties are small when compared with the main uncertainties around location and source term. Nonetheless, work is planned to address a range of uncertainties that have been identified.

- Model validation requirements. The models that were employed in support of the BSA-2012 assessment would benefit from model validation activities. One possibility for the terrain and ecosystem model would be to validate in relation to the reference mires. Model output could be compared with a real mire to determine whether the model resolution is appropriate. In addition, the model could be compared with other mire development models, for example through a future BIOPROTA geosphere-biosphere interface project.
- Evaluation of input data. A formal acceptance procedure will be applied to all data employed in future iterations of the assessment. In addition, a scoping probabilistic tool is being developed that aims to check the variation of different parameters and how they impact on results.
- Model interfaces and modelling of biosphere features and processes. River channels are to be updated along with deposition and erosion coefficients in the terrain and ecosystem model for the next round of assessment. In addition, the hydrological model requires further development to improve the interface with the radionuclide transport model and the land uplift model will be revised to allow uncertainties to be evaluated in a probabilistic way. Consideration is also being given as to whether the modelling time step for the biosphere should be revised from 500 years to 100 years. Moving to a shorter model time step would however create a lot of additional work in understanding (and modelling) biosphere processes such as primary succession as new land areas emerge by land uplift and develop into forests.
- Dose assessment. The landscape model applied for human dose assessment has a complex structure and the degree of complexity required is to be further evaluated. This will include undertaking further research to underpin the model, including an irrigation survey that is taking place in 2014. Criteria for selecting drinking water sources are also to be considered further;

whilst small water bodies are unlikely to be used for human consumption they can be important for animals.

In addition to uncertainties raised in relation to the BSA-2012 assessment, it is recognised that the Finnish regulator, STUK, may revise regulation that may give rise to new scenarios that must be considered in future assessments. For example, an earthquake scenario may be required whereby a canister is split as a result of an earthquake at a time period of 200 years after emplacement.

A number of data gaps are also due to be addressed in the ongoing site characterisation programme. The data gaps are to be prioritised in consideration of modelling needs.

Sampling campaigns are planned to derive river data that was lacking in the 2012 assessment. Additional mire sampling is also planned to derive data relating to mires over time as they develop. Data gaps are also evident for the biota dose assessment, particularly in relation to concentration ratios for identified representative species; it is required under the Finnish regulations that data should be derived from the site by preference and sampling campaigns in agricultural, mire, forest and lake areas are planned. A further uncertainty is associated with the properties of new soils that develop as land uplift results in new terrestrial areas. Sampling is due to take place in the more probable release locations and sorption and the role of microbes will be studied.

It was noted that ICRP Committee 5 have a working group that is to develop guidance on the selection of representative species for assessments and Posiva may wish to provide input to the development of this guidance.

2.4 PROJECT ECORISK – LATEST DEVELOPMENTS IN FLOW AND TRANSPORT MODELLING

Jordi Vives i Battle presented.

Forests are known to plan an important role in element cycling and the global carbon cycle and a project, ECORISK by a coalition of four organisations including SCK·CEN, has been established with the following objectives:

- Evaluate the impacts of climate change and forest management options on both forests their associated ecosystem services (carbon storage, nutrient and water availability, pollutant mitigation);
- Aid decision-making process regarding possible solutions to reduce the impacts of extreme events (e.g. extreme droughts) on sustainable production of woody biomass;
- Optimise forest management options to balance sustainable production of woody biomass and soil carbon and nutrient stocks; and,
- Optimise nuclear waste management policy (trees act as biological pumps).

The ultimate objective is to design a decision support tool capable of simulating forest ecosystem response in terms of health and growth to external drivers, for example global climate change.

There are a number of aspects to the project, including downscaling of a complex climate model to Belgium, modelling nutrient transfer at the soil-root interface, flow and transport modelling in the soil rooting zone and modelling a forest response in relation to environmental stressors. It is intended that each of the models will be capable of being coupled to other models. Hydrological flow and solute transport modelling is being run by SCK·CEN in a sub-project called Ecoflow.

For nutrient transfer, the model needs to allow both water and solute flow to be evaluated, which involves a number of different processes. Consideration therefore needs to be given as to how to make the model realistic without being too complex that it is impractical in terms of application due to data requirements.

A range of radionuclides have been selected that will be incorporated into the model. A number of selection criteria were applied, included availability of data and presence in waste. An interaction matrix type approach has then been applied within the model maker platform that allows processes to be added or removed as the model evolves.

A classic hydrological model approach, based on Richards equation has been applied with trees being represented in a simple way within the provisional model that has been developed in order to investigate effects on hydrology. This simple tree model has now been removed to allow a more complex plant model to be implemented. Retardation is represented by Kd that is not considered constant. Two approaches can be employed to evaluate retardation. Modelling can be performed in PHREEQC, but this is complex. Alternatively, a parametric Kd approach can be employed that takes into consideration pH, organic matter etc. as published in a paper by Steve Sheppard and colleagues.

The Ecoflow model, initially implemented in ModelMaker, has now been converted to the FORTRAN code and is fully coded. The output from the FORTRAN model is being compared with that of another accepted model (HYDRUS) and indications are that the model is performing well for hydrology simulations in sand, silt and loam soils. The model did not however converge with the output of HYDRUS for clay soils. Good agreement was observed however between the two models when different precipitation rates and soil layer thicknesses were considered.

Validation of the solute transport aspects of the model is more difficult due to lack of available means of comparison. The sensitivity of the model to time and space discretisation has been investigated to ensure that there is not a large deviation in output for a relatively small change in parameters such as soil thickness. Work is now progressing to allow the code to be coupled and linked with the main ECORISK code.

A Mol test scenario will be set up (amongst others), involving variable atmospheric conditions and a heterogenous soil profile with different drainage conditions as part of a PhD project that funding has recently been approved for. Further work will also focus on the final integration of Ecoflow with Ecorisk.

Further work is also planned on the parametric Kd approach. In particular, whether or not the Sheppard equations for elements can be considered universally or only applicable to the data within the publication will be investigated. There are various soil types in Belgium and the use of the equations, if transferable, would allow data on Kd to be evaluated without extensive sampling and with less data requirements than for PHREEQC modelling. Initial investigation suggests that the equations may not be transferable to Belgian data and the equations themselves are therefore being studied to see whether parameter modification would lead to a better fit for the data set. This is being investigated within the Eureqa software. This software can be used to generat4e algorithms from a simple algorithm with the best fit being selected and adapted; there can be more than one numerical solution to a problem and, if one is no longer the best then Eureqa moves to an alternative algorithm. Results are due to be published as a scientific paper.

Contributing factors to Kd for the different elements are also being investigated. The best simple regressions have been observed for pH and clay. The different experimental approaches to deriving Kd are also being investigated as understanding the means of derivation can help reduce uncertainty.

The next steps will involve application of the model to scenarios, including the detailed Mol scenario that is under development.

2.5 CURRENT STATUS OF BIOSPHERE ASSESSMENT PROGRAM OF NUMO

Sanae Shibutani presented.

NUMO was established in 2000 to lead the Japanese disposal programme with preliminary investigation areas being announced in 2002 as the first stage of the site selection process. The selection process will proceed in a stepwise manner, starting with a literature study on the long term stability of the geological environment. Preliminary areas will then be selected leading to more detailed site investigations that will include borehole drilling prior to selection of a final site. Public opinion will be gauged throughout the process.

To date, no areas have come forward to say they are interested in being considered as a candidate site. A generic assessment approach is therefore being developed with the biosphere assessment strategy being based on the IAEA-BIOMASS-6 approach, taking into account a wide range of potential site conditions.

The current focus is on the development of models and supporting databases. The assessment model is based on the previous H12 report, with greater consideration of climate conditions and the geosphere-biosphere interface. Different radionuclide transport pathways are considered in the assessment model and alternative topographical arrangements, leading to different types of sites and exposure pathways model considerations such as inland with deep well or coastal release. According to the type of site, representative exposure groups are selected and data requirements identified.

The assessment database is being developed in collaboration with JAEA with work undertaken to identify and prioritise key parameters for which site data will be required. The procedure for acquiring data has been developed. Parameter correlations are analysed to understand how parameters interact. Those data that are independent of a site are being prioritised for update until a candidate site is identified. For those parameters identified for update at this stage, such as data relating to human habits, the first step is to identify the source of the original data and from this to confirm the suitability of the data. Differences in available data, such as new sources from the IAEA and the latest Japanese data for Kd and transfer factors are then identified and, where deemed appropriate, the database is updated. In considering the suitability of the data, thought is given to suitability over the long-term.

Revisions made so far to the database have included the value for ingestion of cow milk with the revised value being around half that of the original value due to changes in diet in Japan. However, which value is more appropriate in the long-term is difficult to gauge. Whether the upper, lower or average value should be applied is questioned. Whilst the choice has only a small effect on the final dose values, the question does arise as to how to represent a lifestyle appropriate for long-term safety assessment.

For Kd, initial data were derived from the IAEA TRS364 publication. However, the most recent revision, TRS472, includes data for Japanese soils so these have been deemed more appropriate. Nonetheless, many of the data in the IAEA publication are for temperate climates whereas East Asia is classified as semi-tropical. A research programme is therefore underway in Japan to determine data appropriate to Japanese conditions and these data will be used to update the database as they come available.

It is planned that work will continue on model and database development for possible sites. Once a candidate site is identified, further development will commence to ensure the site properties are appropriately represented.

2.6 LIFETIME ENVIRONMENTAL SAFETY AT THE LLWR

Trevor Sumerling presented.

On 1st May 2011, LLW Repository Ltd (LLWR) delivered its Environmental Safety Case (ESC) to the Environment Agency. Over a review period of around 18 months, the Agency identified around 90 regulatory issues, regulatory observations or technical queries to which LLWR has responded and provided additional assessments, analysis or information as needed. Subsequently, the Environment Agency declared that the information supplied was adequate to support application for a variation to the environmental permit and an application to vary the permit was submitted in October 2013. Submission of the permit application triggered a statutory process of public consultation. The first part of the public consultation was on LLWR's permit application, as supported by the 2011 ESC previously submitted and additional work since its submission. Once this has been completed, the Environment Agency will draw up a draft decision document that will itself be put to public consultation. A final decision document is expected in the spring of 2015. A request for planning permission is progressing in parallel.

The existing permit allows disposal in Vault 8 only up to the original design (approximately five-metre) stacking height with any waste stacked above this height is stored. The LLWR's permit application is to allow this 'stored' waste to be assessed as its suitability for disposal and to continue disposal into Vault 8 and also into Vault 9 under new Waste Acceptance Criteria (WAC) as supported by the ESC. Capping of Vault 8 (and the old trenches) and in the longer term, development of further vaults is planned, subject to necessary planning permission and environmental permit.

Safety assessments are made for the Period of Authorisation (PoA), i.e. the period during which the site operator holds a permit (previously termed Authorisation) and the site remains under active management, and for the longer term, post-PoA at which time it is assumed active management controls and regulatory oversight have been discontinued.

For the PoA, models are applied to evaluate safety and at the present day this is supported by monitoring. For example, evolved gases and discharges to the marine pipeline, that are relatively small in quantity, are monitored. Radon is the most significant radionuclide for calculated doses, but modelled and measured air concentrations at the site boundary indicate that activity concentrations are not distinguishable from natural background. Calculated levels of C-14 and tritium at the site boundary are below levels of detection. Radioactivity in airborne dust is monitored by high volume air sampler, but activity detected is entirely attributable to naturally-occurring radionuclides, historical discharges from the Sellafield site, and fallout, e.g. from Chernobyl. External doses rates are measured at the site boundary and, at some locations, show a contribution from scattered radiation from the waste in vaults or site operations. Tritium is measureable in groundwater beneath and to the south-west of the site as a result of historical leakage from the trenches.

Different radiological safety criteria apply for the PoA and post-PoA. During the PoA, when the site is under management control, effective doses to members of the public should not exceed a source-related dose constraint of 0.3 mSv/y. In the longer-term, post-PoA, the assessed radiological risk to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year (i.e. 1 in a million per year), which corresponds to a dose rate of 20 µSv/y for a case that is assumed to occur (probability of one). Thus, the assessment of the PoA must cover not only present-day conditions but also projection of doses over the managed lifetime of the site, showing that the site will be managed (e.g. through leachate management and emplacement of engineered barriers) in such a way as to bring the future assessed doses to a level consistent with the risk guidance level. Results were presented that showed the decreasing projected annual doses both to a present-day critical group

and a possible future group, also making use of a water abstraction well to the southwest of the disposal area.

The area around the LLWR site is predominantly rural with agricultural land and low-density settlement to the north and east of the site, and a Site of Special Scientific Interest (SSSI) occupying most of the area to the southwest between the vault and trench areas and the sea. The disposal site slopes from about 20m OD on its northern boundary to about 10m OD at the southern end of the trenches.

A key feature of the site is its proximity to the coast and hence vulnerability to coastal erosion, especially in view of expected global sea-level rise. It is expected that erosion of the disposal area will commence within a few hundred to a few thousand years after present, with the whole disposal area being eroded within approximately one thousand or more years. Given that disruption by coastal erosion recession is the expected scenario, the Environment Agency requires that the same strength of evidence and rigour is afforded to the assessment of the impacts of coastal erosion as to groundwater contamination. Thus, a more detailed collation of evidence, development of model capability and assessment of coastal erosion has been required as compared to the previous safety case submission in 2002.

There is a good understanding of the causes of future sea-level rise and implications for coastal erosion, but large uncertainty in the rate and eventual maximum of sea-level rise, and uncertainty concerning coastal response. Understanding of present-day coastal regime, paleo-evidence and two models of coastal erosion have been employed to estimate the rate of coastal recession for different projected sea-level rise cases. The evidence indicates the disposal facility is likely to be disrupted within a few hundred to a few thousand years, with undercutting of the engineered vaults being the most likely mode of disruption. Heterogeneity of waste forms and heterogeneity of the distribution of radionuclides within the wastes are important factors in assessing the radiological impacts from erosion (and are also important factors when assessing human intrusion).

Future land use must be considered, including the potential for habitation to the southwest of the site, and possibilities for sinking a water abstraction well. The probability of a water abstraction well being constructed to the south of the site has been elicited based on present-day uses of the Cumbrian coastline and this probability is incorporated into assessments of the groundwater pathway.

Significant developments have been made to modelling of C-14 releases in the biosphere and their scientific underpinning, the latter has drawn on experience from BIOPROTA as well as a review of plant canopy atmosphere models. Updated assessments based on this new model capability provide a less cautious evaluation of impacts from C-14 bearing wastes and, hence, the radiological capacity for disposal of C-14 bearing wastes has been extended.

Radioactive contaminated asbestos has been identified as a problem and work has been undertaken to support the assessment of potential long-term impacts so that LLWR is now in a position to consider waste acceptance criteria for this waste.

Assessments of the PoA and longer-term, post-PoA have been performed, but these are not yet integrated and model consistency needs to be further evaluated. Monitoring requirements to provide data in support of assessment of both periods must be considered. The long-term evolution of the repository can only be considered on the basis of the history of the site, and site developments, from first construction.

Studies have been undertaken to look at the feasibility of selective recovery of wastes from the trenches. Thorium and radium-bearing wastes have been identified as those giving the greatest impacts, these in the human intrusion and coastal erosion assessments. The work indicates it would be technically

feasible to recover these waste types and re-package for disposal elsewhere. However, the assessed doses and risk are consistent with regulatory guidance values, the recovery would delay capping works and re-disposal costs would be very high.

A wide range of wastes are disposed at the LLWR and, as such, radionuclide concentrations are not uniform throughout the repository. Doses and risk assessments must take account of heterogeneity:

- at the large scale, i.e. different radionuclide concentrations between different vaults or trenches, or regions of the repository. This was considered and included in the 2011 ESC assessments;
- at waste form / item scale, i.e. radionuclides may be particularly associated with a given waste form or individual waste items may carry activities substantially above the average. This was recognised in the 2011 ESC but not analysed;
- at particulate scale, i.e. it is possible that the waste may contain higher activity particulates that could be cause for concern. The concern arises from experience in the UK of incidences of high-activity particles on beaches in the UK in the vicinity of Sellafield and Dounreay related to past nuclear waste management processes, and also at Dalgety Bay in Scotland where radium contaminated items have been recovered related to historical disposal of debris from incineration of military aircraft.

The last topic was a particular focus of interest from the Environment Agency during their review of the 2011 ESC. In response to Agency regulatory issues, LLWR carried out a series of assessments of radioactive particles based on a methodology previously developed by the Health Protection Agency (HPA), now Public Health England. Subsequently, work has been carried out to identify materials that could realistically give rise to potential for 'active particles' such that encounter (inadvertent ingestion) could lead to a committed effective dose within or above a dose guidance range of 3 to 20 mSv/y, defined by the Agency, and WAC have been developed such that such waste would not in general be accepted for disposal at the LLWR.

The second topic concerns the presence of durable waste items, e.g. large steel engineered items or handtools, that will be deposited on the beach during coastal erosion. These could be the subject for attention by beach users either from curiosity or potential for recovery. A simple model has been developed to calculate dose rates to an individual encountering such 'discrete items', either surface or volume contaminated, of varying mass. The model includes exposure to external radiation and internal irradiation from secondary ingestion of removable contamination from the item or its degrading surface. This has provided a basis for WAC for discrete items within a consignment.

An update was also given on the development of an assessment of radioactive asbestos as presented at a BIOPROTA Workshop in Ljubljiana, 2012, on 'scientific basis for long-term radioactive and hazardous waste disposal assessments'. Improvements have been made to the underpinning data concerning the potential for release of asbestos fibre to air from contaminated soils and from working of different asbestos containing materials. This has enabled firmer and less cautious quantitative estimates of potential impacts to be made.

2.7 SUMMARY OF FIELD AND LABORATORY STUDIES TO EVALUATE THE BEHAVIOUR AND IMPACT OF METHANE IN AGRICULTURAL SOIL

George Shaw presented.

C-14 may be released from a geological disposal facility in the form of methane that may then be transported to the biosphere. What happens to this methane when it reaches surface soils is of

particular interest in safety assessments for the disposal of radioactive waste due to the potential for uptake into plants. If methane is considered as the dominant form for C-14 in a repository then calculated risks are likely to exceed the risk target. Processes dominating doses have therefore been investigated.

Methane can be generated in surface soils by methanogenesis or can be oxidised to carbon dioxide depending upon soil moisture and redox conditions. In anoxic soils, bacterial activity can lead to the procudtion of methane from the acetotrophic pathway or via the hydrogenotrophic pathway which converts carbon dioxide to methane. Soil respiration plays an important role in the formation of carbon dioxide. There can be bidirectional movement between methane and carbon dioxide formation and the release of both across the soil-atmosphere interface. On release from soil, plant canopy dynamics will affect the ability of plants to take up carbon dioxide. To investigate the potential for uptake of carbon dioxide by plants, following release of methane into soil columns, C-13 labelled methane was employed. Laboratory studies were also performed using C-14 and C-13 to show that those studies performed in the field with C-13 were also applicable to C-14.

Four sets of column experiments were performed with injection of labelled methane gas occurring at the base of each soil column. A headspace chamber could be added to allow sampling of gasses released from the top of the soil columns. Both undisturbed and repacked, mixed soil columns were studied and soils were either vegetated or un-vegetated. Two sets of field experiments, each taking 1 year, were also performed. In the first field experiment, attempts were made to recreate laboratory column experiments by introducing sleeves around the soils by hammering these into place and then excavating around to allow samplers to be inserted. This was however difficult to achieve and samplers were frequently broken. In the second experiment, shallow sleeves were inserted as an alternative with long tube samplers then being inserted into the soil at 45 degree angles. This approach was more successful in producing experimental data.

Various soil and meteorological parameters were measured, including volumetric water content as a function of soil depth. A higher mean water content was observed in un-vegetated plots as a result of the uptake of water by vegetation. Vegetated soils were also observed to have a higher porosity due to the root system of the crop within the soil. Tortuosity has been calculated from porosity and water content measurements.

From the measurements taken of C-13 it was possible to track movement through soil columns and to quantify the diffusion of component gases (carbon dioxide and methane). Similar results were observed from both laboratory and field experiments so there is confidence that the data derived from laboratory studies can be applied to field conditions.

Carbon dioxide formation and transport was investigated and was observed to increase following methane injection at the base of the column; a peak was observed 10 hours following injection after which time concentrations tailed off. The delta-carbon dioxide peak was smaller than that observed for methane. It was considered that a good proportion of carbon dioxide was formed, but that rapid movement of carbon dioxide through the soil resulted in the small delta values. The observed time lag in carbon dioxide formation following injection is thought to result from the period of time required for soil microorganisms to consume the methane. Conversion of methane to carbon dioxide is an enzyme driven process comprising four steps; conversion therefore is not immediate. The kinetics of the conversion are not reported in the scientific literature and have therefore been studied and it is considered that gives a reasonable argument for the time lag observed. Not all methane will be converted to carbon dioxide; some carbon will be converted into biomass. Of the methane injected in laboratory studies, between 66 and 75% was oxidised to carbon dioxide. In field studies, 80% was oxidised in the second year experiments in both vegetated and un-vegetated plots.

Methane diffusion coefficients have been estimated in relation to water content and porosity data for both laboratory and field experiments and estimates of methane oxidation rate constants have also been made.

A model has been developed to represent the behaviour of methane in soils based on the observed results from field and laboratory studies. Assumptions have had to be made regarding factors such as biomass production in soils to get the model to fit the data and it is acknowledged that these assumptions are not well supported.

A C-14 study has also been performed under laboratory conditions. Repacked soil columns were used and the experimental approach mirrored that applied to C-13 experiments. It was not possible to distinguish between methane and carbon dioxide in the C-14 experiments due to the analysis procedure, hence a slight discrepancy was observed with the C-13 experiments.

Overall, the experiments showed a rapid diffusion of methane in soils with oxidation being best described by first order reactions with a time lag in carbon dioxide production being observed that is likely due to the biochemical pathway involved. The summary report of the study will be made available once published and comments and alternative hypotheses for the results observed are invited.

2.8 RWM PERMAFROST WORK

Simon Norris presented.

RWM is interested in developing knowledge on how the geosphere responds to climate change and the potential impact that permafrost could have on a geological disposal facility. Such a facility in England and Wales could be located at a depth of between 200 and 1000 m. If located at the shallower depths, permafrost may impact directly upon the engineered barriers of the disposal facility. For a deeper GDF, permafrost formation could affect e.g. groundwater chemistry in the host rock. The impact of such permafrost-related changes would need to be assessed in a safety case

Permafrost is defined as ground at a temperature below a 0º isotherm for at least two consecutive years, with ground temperature driven by cyclically changing air temperature.

In a recent study for RWM to ascertain possible depths of permafrost, ten locations around the UK with borehole and core records available were randomly selected (Figure 2-1) and site geology was considered along with heat flow data and thermal conductivity of rocks (these being important factors when considering permafrost). How temperature has changed over the past glacial cycle was reconstructed, including ice sheet development (Figure 2-2). Various data sets were available to support reconstruction, including sea surface temperature and land temperature studies with the combined data allowing a temperature-time dataset to be established for the UK over the last 140,000 years. Comparison with other climate datasets showed broad similarity with that developed as part of the RWM study. The temperature profile was used to evaluate when and where ice sheets may have been present in the UK with the south of the country not thought to have been affected by ice sheets.

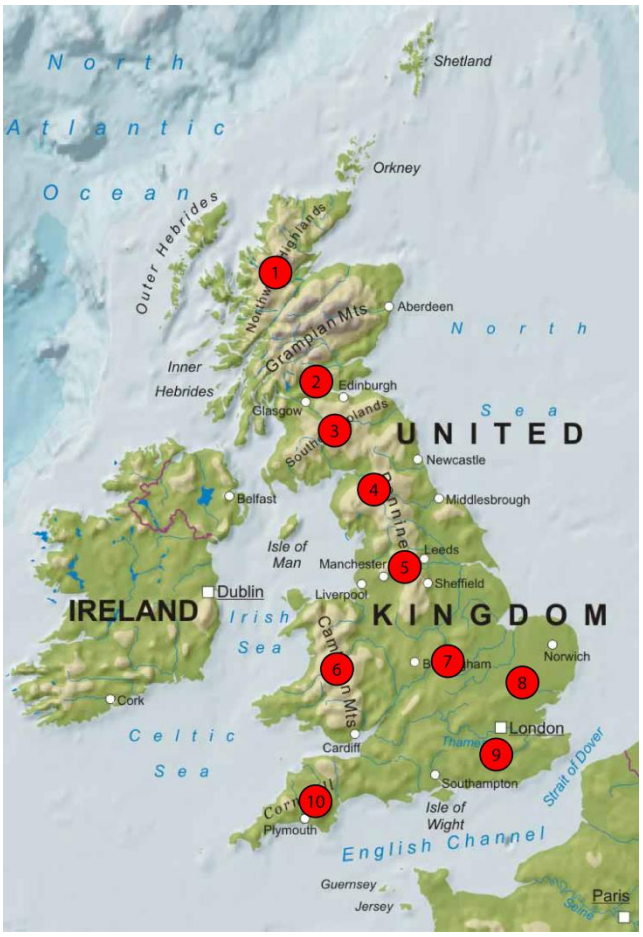

Figure 2-1. *Study locations in the RWM permafrost study.*

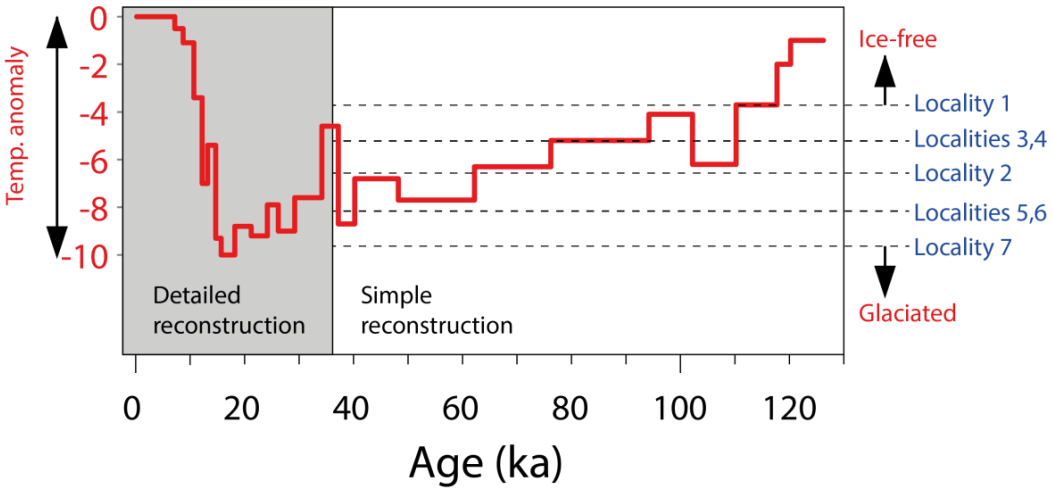

Figure 2-2. *Ice sheet coverage of different regions of the UK. Localities correspond to those depicted in Figure 2-1 (see also Table 2-1).*

Models have been run for each of the ten localities, taking into account basal temperature. Currently groundwater flow and its impact on sub-surface temperature is not considered. Consideration was given however as to whether dry or wet based ice sheets would develop. Once the surface temperature is known, subsurface temperatures could be evaluated. Results of the model runs indicate that the greatest permafrost penetration would occur in the northwest Highlands (Table 2-1). A maximum penetration of 305 m was modelled for the Southern Uplands during a cold climate. An example from models run for the Dartmoor region (denoted 10 in Figure 2-1) is detailed in Figure 2-3. Uncertainty in permafrost development requires consideration.

Table 2-1. *Modelled permafrost penetration at ten sites around the UK during average-estimate and cold-estimate climates.*

Location (location number from Figure 2-1)	**Maximum depth of permafrost (m) due to average estimate climate**	**Maximum depth of permafrost (m) due to cold estimate climate**
Dartmoor (10)	80	220
Weald (9)	65	245
East Anglia (8)	65	245
South Midlands (7)	30	180
Mid-Wales (6)	105	215
South Yorkshire (5)	90	180
Stainmore Trough (4)	20	205
Southern Uplands (3)	150	305
Midland Valley (2)	110	215
Northwest Highlands (1)	180	235

The past climate has been used to evaluate possible future climate conditions. On average, the maximum permafrost development across the UK is calculated as 180 m. If anthropogenic warming is considered, no permafrost impact on a GDF is likely to occur for the first 180,000 years post closure.

Geological evidence for permafrost during previous cold stages of glacial cycles is available from the investigation of near-surface geology, although only for shallow depths (a few 10's of metres). Although there is no evidence for deeper permafrost penetration, this does not mean that it didn't occur. Rather, it could be that we just don't know what evidence to look for, or that a one-time present signal is now no longer present.

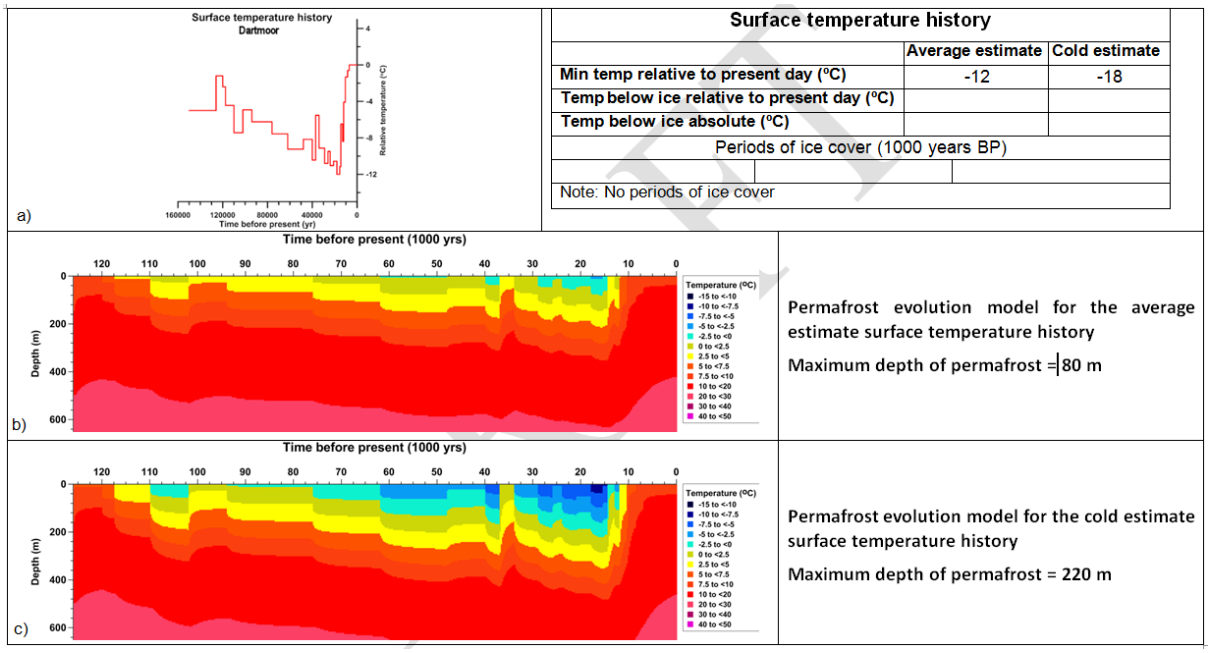

Figure 2-3. *Results of permafrost evolution at Dartmoor from the period from 126-0 kyr BP for the average estimate surface temperature history (upper) and cold estimate surface temperature history (lower)*

Further work is planned in relation to permafrost modelling following various recommendations made as a result of RWM's work programme to date, e.g. how permafrost could affect the mineralogy of rocks could be considered.

Permafrost is not always a negative consideration for geological disposal; it can affect the rate of groundwater recharge / discharge, giving a greater decay time in the geosphere or engineered barrier system for GDF-derived radionuclides. Furthermore, whilst people can live in areas affected by permafrost, larger subsistence areas are required; this could reduce exposure potential to GDF-derived radionuclides. The effect of permafrost growth and decay on the properties of the geosphere need be considered.

2.9 RESEARCH AND ASSESSMENT PRIORITIES OF NON-PARTICIPATING MEMBER ORGANISATIONS

Graham Smith presented some research and assessment priorities identified by BIOPROTA member organisations that were unable to attend the workshop. The following interest areas were raised.

- There is continued interest in C-14 dose assessments from many organisations, including BIOPROTA members and other organisations, such as AECL (Canada) and CNCAN (Romania). Several organisations have expressed an interest in the disposal of NORM and other radioactive waste within a singular disposal facility. Management strategies and assessment approaches can differ for these wastes and there may be a need to address consistency issues if disposal in the same facility is considered. A similar issue is disposal of VLLW in conventional landfills, for example in countries that are dealing with remediation of legacy sites or decommissioning of large facilities. This leads to a broad range of interests in comparison of assessments for disposal of radioactive and other hazardous radioactive waste.

- Interest has been expressed in assessments that support selection of options, and for the selected option, assessments that support demonstration of optimisation of implementation of that option.

3. UPDATE ON COMPLETED AND ON-GOING BIOPROTA PROJECTS IN 2013-14

3.1 BIOPROTA SPACE PROJECT

David Copplestone presented.

The SPACE (Scales for Post-Closure Assessment Scenarios) project aims to address uncertainties in spatial and temporal scales for wildlife in long-term safety assessments.

The environment has become part of the system of requirements for radiation protection and is being incorporated across the board in terms of radiation exposure. However, biota range from immobile (e.g. plants) to large ranging (e.g. wolf) in habits and spatial scales therefore require consideration for assessments relating to radionuclide impacted sites. Furthermore, extra time steps may need to be considered in assessments due to the different lifespans of different species. Both spatial and temporal aspects therefore need to be considered to ensure protection of different species. Within the SPACE project, an approach is being developed, taking into account modelling requirements that could be employed in long-term assessments. A demonstration test case will be undertaken to then evaluate whether the approach works.

The assessment approach for the radiation exposure of people is quite well defined and is an established process whereas the approach for evaluating the exposure of biota is still evolving, both in terms of the assessment process and understanding. In incorporating biota to an assessment, the objective is to avoid adding additional unnecessary complexities; planned exposure situations are not considered to be a particular issue for biota, but there is nonetheless a need to demonstrate protection.

The focus of protection for biota is on populations rather than individuals. Therefore, in undertaking an assessment, the area required by individuals making up a population needs to be considered. In long-term assessments there are added complexities; the species comprising communities will change over time as climate changes and the landscape evolves. The need to consider such changes will largely be driven by regulatory criteria. Irrespectively, the focus should be on undertaking an appropriate and fit-for-purpose assessment.

For the purposes of the project, suitable species have been identified by considering spatial and temporal ranges and the range of reference animals and plants in the ICRP assessment approach in order to make maximal use of available data required for population-level assessments. Data have then been collated, using traceable sources wherever possible, on spatial and temporal characteristics of each representative species. Organisms have then been clustered according to whether they are immobile or have small, medium or large individual ranges for spatial scale considerations. The number of individuals comprising a sustainable population was also required. There are different approaches to this, but for the purposes of this project, a multiplier of 40 has been applied on the home range of an individual. In terms of population scales, a large range was derived; for example, a few tens of metres for earthworms versus over 9000 km^2 for grey wolf (although for wolf it may be appropriate to consider a pack rather than using the multiplier approach). Issues can ensue in assessments from both ends of the spatial scale.

In terms of temporal scales, species were clustered according to lifespan. However, since releases from a disposal facility would be gradual over long timescales it was considered that there is probably no argument for increasing modelling time steps for biota; rather species impacts could be considered using the same time steps as used for people.

The first approach to spatial modelling was to use site data from the SKB Forsmark SR-Site assessment. However, upon examination of the data, the spatial representation of contamination was deemed insufficient for the purposes of demonstrating the SPACE approach; one or two data points were presented per basin with the smallest basin being 77,000 m^2. Such a resolution would not allow very small organisms to be represented in the evaluation; a finer resolution was required to demonstrate whether or not spatial scales are important for biota assessments. An alternative approach was therefore adopted for an initial scoping test case whereby a grid of 100 x 100 m was assumed within a 400 km^2 area. Within the grid, 3 points were randomly selected as release points to the biosphere with dispersion occurring from each of these points based on masked dispersion plumes from an assumed groundwater plume direction. Both contaminated and uncontaminated areas result within the grid area. 1000 points within the grid were then randomly sampled to evaluate the average concentration that organisms are exposed to for each radionuclide (radionuclides being clustered according to relative mobility in the environment), both with and without zero numbers for each point.

A simple linear equation has been initially used to represent dispersion of radionuclides, but it is proposed that a sigmoidal equation is used in the final test case. A unit activity concentration was employed and realistic activity concentrations then derived on the basis of SKB SR-Site data; the maximum activity concentration, irrespective of time, for each radionuclide has been employed. Data from the grids is then used as input to ERICA. To test the approach, four test species were initially selected. Concentration ratios from the wildlife transfer parameter database have been applied, which underpins the IAEA transfer handbooks and ICRP Publication 114. Initial results indicate that dose rates are very low and are similar, irrespective of the size of population range. These initial results indicate therefore that spatial scales do not make that much difference in terms of biota dose rates, but the final test case needs to be run for all other SPACE assessment species before a final conclusion can be drawn. If zero data are removed however (i.e. assuming that those individuals in uncontaminated areas do not contribute to the population) then some differences in dose rate are observed.

The results of the final test case will be tabulated to clearly show the different ways of doing scaling and allow interpretation as to the degree of difference in dose rates as a result of scaling. Further refinement of the initial test case will be made prior to running the final version. This will include further consideration of the population multiplier with respect to assessment species; for example, it may be more appropriate with wolves to consider a typical pack rather than a larger population as derived by the multiplier approach.

Finally, it was noted that there are various other inter related work programmes occurring internationally (e.g. MODARIA) and interactions between these and the SPACE project are being maintained since work on spatial scale has implications for other discharges, not just those from geological disposal facilities.

3.2 INTERNATIONAL WORKSHOP ON C-14: DATA, ECOSYSTEMS AND DOSE ASSESSMENT

Karen Smith presented.

An international workshop on ‘C-14: Data, Ecosystems and Dose Assessment’ was held in Aix-en-Provence from 1-3 April 2014, hosted by IRSN. The workshop follows from previous C-14 work programmes within BIOPROTA, including a workshop in 2013 that was hosted by SKB in Stockholm, the report of which has recently been published in the SSM reports series. Whilst a number of work programmes have been undertaken on C-14 in terms of long-term safety assessments, there remain a number of uncertainties. For example, in relation to terrestrial assessments, there is uncertainty around the fate of C-14 labelled methane entering soils, whether release is direct to atmosphere or whether there is microbial oxidation with subsequent plant uptake of resultant carbon dioxide. There is also

uncertainty associated with the representation of plant canopy dynamics in assessment models. Less work has been done to date with regard to C-14 in aquatic environments hence a number of uncertainties have been identified. These relate to:

- Multiple carbon pools with differing rates of transfer between;
- Cycling / transport of C-14 is affected by water body conditions such as the presence of a thermocline, pH, water exchange etc.;
- The form in which C-14 is present, which affects its fate within a water body;
- Rate of carbon dioxide exchange across the water-atmosphere interface and rate of loss of particulate organic carbon to sediments; and
- What carbon pools are accessed by biota as a result of feeding preferences and habitat occupancy, not all of which may be contaminated.

The workshop was organised to allow exchange of information on recent work programmes of participant organisations, including new modelling work and field research and data and to discuss how this information might be used to improve dose assessments. Furthermore, the workshop aimed to evaluate the scope for further work that would help improve representation of key processes and justification of model approaches for specific sites. The workshop was attended by 23 participants from 9 countries, comprising BIOPROTA member organisations (IRSN, EdF, Andra, BfS, OSU, SSM, Ciemat, SKB, Posiva) & their technical support organisations plus representatives from the IAEA and the NERC Radiocarbon Laboratory (University of Glasgow) and a range of presentations were made covering subject such as:

- IAEA C-14 programmes, past and present;
- Latest C-14 model developments by Posiva, SKB, IRSN, SSM and LLWR;
- C-14 model uncertainty in aquatic environments and in forests and mires; and
- Potentially available data sets, including
    - IRSN monitoring of grassland site near Cape de la Hague
    - University of Nottingham field and laboratory studies performed for RWM
    - Ongoing analysis of groundwater, soil gas and plant activity concentrations at Duke Swamp
    - EdF fish data from historical monitoring and a current research programme following C-14 release to river and speciation and transfer to organisms.

A number of potential future work programme subject areas were identified, along with opportunity to collaborate with other work programmes relating to C-14, including:

- Interaction with the CAST 5 year research programme that is just starting and may have implications for C-14 source terms, and continued interaction with the IAEA;
- Comparison of biosphere dose conversion factors and IAEA SRS-19 screening coefficients;

- Application of models to a scenario developed around monitoring data such as:
    - The IRSN La Hague terrestrial data set
    - The RWM / University of Nottingham terrestrial field data
    - Wetland data from Duke Swamp
    - Aquatic data from historical Canadian Shield lake experiments or from EdF river monitoring or the application of models to a well-characterised lake
- Comparison of detailed ecology models (carbon fluxes and biomass) with simple C-14 models to investigate differences and uncertainties in terms of output; and/or,
- Investigating the effect of climate on carbon cycling in sediments and soils.

These different subject areas are being considered for a forward programme on C-14.

3.3 AN EXPLORATION OF APPROACHES TO REPRESENTING THE GEOSPHERE-BIOSPHERE INTERFACE IN ASSESSMENT MODELS

Graham Smith presented on behalf of Mike Thorne.

Models for the geosphere-biosphere interface, GBI are, overall, not as well developed as those for various host rock types or for reference biospheres. A project was therefore undertaken within BIOPROTA to:

- identify the features, events and processes that may need to be included in conceptual models of the GBI;
- evaluate existing understanding of those processes; and
- consider how mathematical models could be developed on the basis of such understanding.

The project ran from December 2012 with delivery of a draft final report to sponsors in May 2014 with the following key stages:

- Initial review of how the GBI is treated in existing assessments, including
    - UK: Generic studies of deep geological disposal of intermediate-level wastes
    - US: Proposed deep disposal of spent fuel and vitrified high-level waste at Yucca Mountain
    - Sweden: Proposed deep disposal of spent fuel at Forsmark
    - Finland: Proposed deep disposal of spent fuel at Olkiluoto
    - France: Proposed deep disposal of high-activity, long-lived waste in clay (Bure site)
    - Canada: Deep disposal of low- and intermediate-level waste at the Bruce site, Ontario
    - Switzerland: Generic studies of the deep disposal of various categories of radioactive wastes

- First Workshop to discuss the findings from the review;
- Development of an overall methodology for generating conceptual models of the GBI and application of that methodology to illustrative examples;
- Second Workshop to discuss the proposed methodology and examine issues related to the translation of conceptual models into mathematical models; and
- Production of a draft final report on the work.

A staged method was developed that involved:

- Identification and justification of the geosphere-biosphere sub-systems;
- Description of GBI;
- Characterisation of the GBI; and
- Development and application of mathematical models.

The overall methodology is intended to be applied within the framework of a specific assessment context, with the assessment context comprising the various components set out in IAEA-BIOMASS-6. The methodology for development of a conceptual model of the GBI for transitions between two states of the system has only been explored to a limited degree.

It was considered that the role of a GBI may first emerge when the overall disposal system is being conceptualised for assessment-modelling purposes, i.e. it may not be useful for site characterisation. Although the GBI may be found useful in conceptual modelling, this utility may not carry over into mathematical modelling, where various tools may be employed to evaluate the significance of various subsets of processes identified as being of potential significance. Nonetheless, the conceptual model of the GBI may be used either to inform development of such mathematical modelling tools, or to audit the existing set of available tools. The GBI or GBIs adopted will be system specific and it may be useful to consider the extent to which GBI characteristics might differ between various contexts.

Although the GBI can, in principle, be defined both for deep and shallow disposals of solid radioactive wastes, in practice, in the case of shallow disposal, the repository is likely to be embedded in a zone that is relatively stable, but that is susceptible to significant change over the assessment period. Thus, the repository may be considered to be embedded in the GBI rather than being located in the geosphere below it.

In many circumstances, it will be appropriate to define the GBI to encompass the whole region down from the ground surface to some depth in the host rock. However, in other contexts, it may be useful to focus on a region with an upper boundary some distance below the ground surface, so that the emphasis is on hydrogeological, hydrogeochemical and geomicrobiological processes. In this context, further work is required on characterising and modelling geomicrobiological processes of relevance.

Within the overall context of interglacial conditions, two classes of GBI require consideration, i.e. those associated with wells and those associated with groundwater discharge. In the case of wells, there is little evidence that the time development of the environment needs to be taken into account, but for groundwater discharge the timescales of landscape development may be comparable with the timescales over which radionuclides move through the GBI and an explicit representation of that landscape development may be required.

Conceptual models of the GBI would typically be translated into comprehensive, process-based mathematical models. These models would typically be used in exploratory studies to determine the principal controls on assessment results and thus to inform the implementation and parameterisation of simpler, assessment-level models. A wide range of mathematical and computational tools is available for addressing issues relating to the GBI and it is likely that most issues could be addressed using these tools individually or in combination with the possible exception of landscape development where existing models are primarily descriptive, rather than process-based.

Models of the GBI need to be representative; need to identify the weakest link in the model. This may be defined as 'what is not genuinely representative'. Models of the GBI may therefore need to go one step beyond what is required for assessment purposes in order to allow simplified, abstracted models for use in assessments, to be developed.

Further work areas have been identified as a result of the project. These include:

- Exploring priorities for focusing on specific radionuclides of common interest to long-term safety assessment; and,
- Using a natural or anthropogenically modified natural test system as a means to facilitate engagement with specialists in other disciplines. Potential candidates include mires or wetlands since they are of interest to many GBI project participants and are useful for exploring relationships between hydrological, hydrochemical and biological processes. These sites are also of interest to BIOPROTA participants with a specific interest in C-14.
- It was also noted that reservoirs in the UK are monitored by CEH and data on hydrology, hydrochemistry etc., may be available that spans some decades, which could be of use in a future GBI programme.

3.4 SCIENTIFIC BASIS FOR LONG-TERM RADIOACTIVE AND HAZARDOUS WASTE DISPOSAL ASSESSMENTS

Graham Smith presented.

A workshop was held in Slovenia in May 2013, hosted by ENSI and GEN on scientific basis for long-term radioactive and hazardous waste disposal assessments. The objective was to allow discussion and comparison of:

- assessment methods and endpoints for disposal of radioactive and other hazardous waste;
- key processes which dominate the release and disposition of radionuclides and other pernicious pollutants within the environment, following disposal;
- timeframes for assessment and approaches to dealing with environmental change
- methods for assessing effects on human health and the environment;
- assumptions for human behaviour and land use, and how that affects the potential for impacts both on human health and on the environment;
- approaches to addressing uncertainties; and
- approaches to addressing low probability events which have high consequences.

By sharing experience on the above topics, it was intended that ideas for complementary, consistent and appropriate scientific support in different assessment contexts could ultimately be developed.

There were 33 participants from 12 countries at the workshop, representing a range of operators, regulators, researchers and technical support organisations, not all of which were linked to radioactive waste disposal. A range of presentations were made on the different assessment tools available, interpretation of results and application to decision making and on site investigation and characterisation methods and on scientific techniques available for more detailed investigations.

Questions and challenges arising from the workshop were that:

- Endpoints for environmental protection are not clear or consistent and that endpoints for radioactive waste disposal assessments are not same as those for hazardous waste disposal assessments (for example, for hazardous wastes it is often the most at risk person that is the focus whereas for radioactive waste it is an average person);
- Scientific and regulatory basis for consistent management are lacking, at least for the long-term;
- There are concerns about understanding of synergistic effects, it being recognised that synergies can be hard to identify;
- Effective containment can lead to higher 'risks' – measures reducing one risk can lead to increases in other risks and options appraisal may therefore be required;
- Resources are not always applied in proportion to the hazard, but if endpoints are not known it is difficult to ascertain if you have a proportionate approach;
- There can be issues relating to priorities between land use planning rules and repository risk assessment and which should support the other; and
- It is considered that different industrial, technical and scientific communities may not be not working together as coherently as they might and how to improve upon this was questioned.

As a result of presentations and associated discussions it was concluded that continued interaction between the different assessment communities would be beneficial, including hazardous waste disposal, NORM management and disposal, and post-disposal safety for radioactive waste communities. Further analysis of the differences in protection objectives and assessment endpoints was also considered to be potentially beneficial as understanding the rationale for differences could be used to promote closer harmonisation where that appears appropriate and could provide and support the need for differences, again, where that is appropriate. One possible subject area for a further technical forum was identified. There may be merit in considering how the EU Groundwater Directive is applied in different countries and its implications for long-term radioactive and hazardous waste disposal assessments. Optimisation techniques for radioactive and hazardous waste assessments could also be evaluated and compared in terms of how assessments help to select between options.

The report of the workshop has been finalised and is available on the BIOPROTA website.

4. OVERVIEW OF PARALLEL INTERNATIONAL WORK PROGRAMMES

4.1 MODARIA BIOTA WORKING GROUPS 4, 8 AND 9

Jordi Vives i Battle and David Copplestone presented.

There are two working groups within the current IAEA MODARIA programme focussing on biota dose assessments, WG8 on biota modelling and WG9 on modelling biota populations. A further working group (WG4) is focussed on data supporting assessments for both biota and people.

4.1.1 Working group 4

Within working group 4, there has been a focus on Kd with a workshop running in Oslo in parallel with the BIOPROTA annual workshop. Whilst it is known that there is a large variability in Kd values according to environmental conditions, it is often the case that single values are relied upon. It is therefore intended that pdf's will be developed as part of the WG4 programme, various problems are being encountered however, not least of which is the availability of sufficient data points; density functions require in excess of ten data points. There is a move away from the use of arithmetic means toward geometric means. Kd data are being evaluated with data being excluded where necessary, for example where data relate to clay rather than soils. Only where exclusion is fully justified are data removed to maintain transparency.

Consideration is also being given as to appropriate factors that could be applied to allow data to be clustered and to allow a greater site focus when selecting data to apply within an assessment. One focus of the Oslo workshop will be whether stable analogues can be used to represent some radionuclides.

It is intended that a database, similar to the wildlife transfer parameter database will be constructed for Kd. Free access to summarised data will be allowed, but not to raw data due to copyright issues.

Concentration ratios are also of particular interest; a wildlife transfer TRS has been completed, but is not yet published. A large number of data gaps are evident and WG4 therefore aims to consider how to prioritise radionuclides for which CR data are required, for example, there are large CR gaps for the ICRP RAPs and data fill approaches are therefore required. One input to this has been information on source terms to which BIOPROTA contributed. This information is being used in combination with exposure pathways to prioritise radionuclides for which CR data are required. Once source terms have been evaluated, the relative importance to internal dose can be evaluated by considering CR analogues or by applying conservative assumptions to address data gaps. Even when CR data are available, there is a need to evaluate whether the data are reasonable and underpinned by sufficient numbers of data points.

4.1.2 Working group 8

Working group 8 is focussed on addressing uncertainties in biota dose modelling. Particular areas of focus are on spatially heterogeneous environments, voxel phantoms versus ellipsoids for dose calculations and the development of a guidance document on lessons learned from biota assessment work undertaken in the IAEA EMRAS I and EMRAS II programmes.

In terms of heterogeneous environments, the group are trying to understand how heterogeneous contamination relates to the exposure of biota populations. A data set has been identified from Sweden where moose have been tracked using GPS collars and maps are available for the area indicating Cs

contamination. Those who have undertaken the monitoring have agreed to work with the group. One objective is to help develop understanding of how animals interact with the environment; some may avoid certain contaminated areas if there has been detriment to the habitat whereas the current approach in assessments is largely to assume habitation of the most contaminated areas at all times.

For biota dosimetry, simplified ellipsoids are used as standard to allow internal and external dose rates to be computed. However there is some uncertainty around how appropriate ellipsoids are in representing some organisms, particularly plants. Voxel phantoms are produced by making CT scans of an individual from which models can be derived that take account of the physical shape and different tissues of an organism. The degree to which voxel phantoms can improve understanding of dosimetry for biota is uncertain; in 2007 a study was performed that demonstrated that there is a maximum 30% uncertainty for some radionuclides through use of a simplified ellipsoid, but uncertainty was much less for others. The work with voxel phantoms may be useful however in developing a greater understanding of dosimetry in relation to particular tissues thus improving understanding of effects studies. There is a tendency at present for the voxel phantoms to be developed for the ICRP RAPs.

The content of a lessons learned document have been agreed and work is now ongoing to produce that content. The document will include information on how to adapt models to certain assessment scenarios to achieve the required objectives such as evaluating dose rates to tree roots within soils. Advice will also be given as to how data gaps in parameter values could be addressed.

4.1.3 Working group 9

The biota population modelling group leads on from work undertaken in the EMRAS II programme, but also has links to STAR population modelling tasks. The ultimate objective is to have better models for better regulation by making the link between the modelling of individuals and populations that are the endpoint of protection and improving predictability by making models more realistic to the wildlife situation. Whether or not eco-physical processes can be incorporated into models to represent population dynamics is being investigated. It is not intended that detailed and overly complex models will be developed; rather, practical tools are required that can be readily applied in assessments. The plan is therefore to create a conceptual basis for population modelling. A further study area is whether acute radiation effects data can be used to represent chronic exposure effects, which would make maximal use of available effects data, much of which is derived from acute exposure experiments.

To date, a relatively simple population model has been developed and typical behaviour evaluated for population dynamics in terms of morbidity, reproduction and mortality. Effects data are used to evaluate the proportion of impact in relation to dose. Modelled dose rate data have been found to compare well with effects data, taking into account individual variability in responses.

4.2 MODARIA ENVIRONMENTAL CHANGE WORKING GROUP (WG6)

The objectives of MODARIA working group 6 on environmental change are to:

- Define key processes that drive environmental change (mainly climate), and describe how a relevant future may develop on a global scale. These drivers are quantitative and can be extracted from existing scientific consensus on global historical climate evolution.
- Develop a conceptual framework that is valid on a global scale, and consider how that can be downscaled to provide information that is needed for site specific assessments.
- Apply the conceptual framework to case studies for particular sites to illustrate the evolution of site characteristics and the implications for the dose assessment models.

The focus is on radioactive waste disposal assessments that can be affected by changes in climate. There is a need therefore to consider whether future climate will be similar to past cycles or whether anthropogenic influences will cause significant variation. It is hoped that a consensus opinion can be reached around this issue. If a consensus cannot be reached then all alternatives will be documented. In downscaling global climate to a site, implications for how the biosphere should be considered will be documented.

To date, the working group has produced a broad report structure as follows.

Executive Summary

Road Map/Flow Chart of Methodology

1. Background, Objectives and Scope

2. Typography of Facility Types and Timescales

3. Controls on Long Term Climate Change

4. Representing the Climate System

5. Prognostic Modelling of Global Climate

6. Downscaling to Regional Scale

7. Influence of the Climate System on Geosphere and Biosphere

8. Applying Narratives to Relevant Futures at Specific Sites

- Belgium, Mol Region
- Switzerland
- Forsmark, SFR and SR Site
- Sierra Morena, Cabril
- Lowland Britain
- Others invited… France, Finland…

9. Analysing Process Understanding and Confidence

10. Conclusions and Recommendations

4.3 ICRP FRAMEWORK FOR PROTECTION OF THE LIVING ENVIRONMENT UNDER DIFFERENT EXPOSURE SITUATIONS

David Copplestone presented.

ICRP publication 124 on a framework for protection of the living environment under different exposure situations has recently been published and a peer-reviewed paper will be available in the near future.

There are a number of questions that arise in relation to protection of the environment, such as:

- What are the protection objectives under different exposure situations?

- What plants and animals are of interest and how to select an appropriate subset?
- What effects are of relevance in evaluating radiation impacts?

The ICRP objective for protecting the living environment is to prevent and reduce the frequency of deleterious radiation effects to a level where they would have negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities and ecosystems. Reproduction is largely considered to be the most relevant endpoint in relation to this objective, but others endpoints can also lead to deleterious effects on populations. For example, early mortality reduces the ability to reproduce and reduced morbidity may affect an individual's ability to attract a mate.

Effects data for the ICRP RAPs and dose conversion factors (DCFs) have previously been published in ICRP Publication 108, which provides the basis for dose calculations to be undertaken. The RAPs themselves were selected as points of reference for which data could be collated to allow dose – effect response relationships to be established and to allow typical assessments to be undertaken. Derived consideration reference levels (DCRLs) have also been published. Effects data have been collated for each of the RAPs and the DCRL level set in consideration of the availability of data and reported effects; each DCRL is an order of magnitude band at which deleterious effects might start to be observed. They are not intended to be used as limits; rather, they are intended to be used to orientate an assessor. Application of DCRLs for the different families can help to avoid instances whereby a generic assessment criteria, such as the ERICA screening value, is applied and interpretation is driven according to the most exposed organism, rather than the most radiosensitive.

In terms of planned exposure situations, which would encompass radioactive waste disposal, the ICRP stance is that exposures should remain below the lower band of the DCRL; the concept being to avoid planned exposures where effects could start to be observed and for the DCRL to be applied as a constraint. However, exposure calculations should encompass all sources. It is noted that the lower band of the DCRL for mammals etc. is currently set at 4 µGy/h, which may be too low. Whilst the concept is considered correct, it has been acknowledged that bands may not always be correct and the DCRL bands are therefore to be further considered and revised where justifiable.

In existing situations, ICRP considered that, where exposures exceed the DCRL band, it would be reasonable to aim to reduce activity concentrations to levels that would reduce exposures to within the DCRL band. Biota assessments would not however be considered in isolation, human dose assessments would also be required. People would ultimately be the focus of protection, but consideration should be given to options that also benefit the environment.

For emergency situations, calculations could be performed to ascertain likely dose rates for biota and evaluate the degree of effects that might be observed. Management decisions would not be made as to what to do to protect the environment during the emergency phase as the focus would necessarily be on protecting people, but it may be appropriate to consider the environment during the recovery phase.

Work is continuing with ICRP Committee 5. Provision of guidance is being considered on undertaking assessments, including selection of representative organisms for assessment and how they may relate to RAPs. Consideration is also being given as to whether there are groups of organism that are not in any way represented by the RAPs, such as freshwater turtles. A radiological impact assessment document is planned. The document is likely to include maximum concentrations of radionuclides in air, soil and water in relation to both people and biota exposure assessments. In most instances, exposure of people will be the most limiting case, but biota exposure may dominate on occasion.

4.4 IUR WORKSHOP ON THE HARMONISASTION OF RADIOECOLOGY RESEARCH

Graham Smith noted that an International Union of Radioecology (IUR) workshop was being organised on the subject of harmonisation of radioecology research programmes with a particular objective to optimise the identification of key research priorities in radioecology research. The workshop was due to take place 19 – 20 June.

A range of different organisations has been invited to participate in order to promote joint understanding of research needs, coordination of efforts to address those needs, and avoid gaps and duplications. Organisations due to be represented include international bodies such as IAEA and ICRP, and others with a regional or technical interest. The BIOPROTA Technical Secretariat has been invited to present priorities for radioecology research that support the needs of the solid radioactive waste disposal community. The output of the workshop is due to be presented at the ICRER conference that is being held in Barcelona in September.

4.5 THE NERC RADIOACTIVITY AND THE ENVIRONMENT (RATE) PROGRAMME, WITH A FOCUS ON TREE

David Copplestone and George Shaw presented.

The NERC RATE programme (www.bgs.ac.uk/rate) is a five year research programme within the NERC pollution and human health strategic theme that is part funded by RWM. The programme will run until 2018. It includes a variety of priority areas including:

- Biogeochemical coupling, including deep multiphase transport processes;
- Technological innovation for rock mass characterisation at a range of spatial scales;
- Learning from natural radioactive analogues and made-made contaminated environments (natural laboratories);
- Innovative approaches to ecosystem/food chain radionuclide uptake and transport processes for key radionuclides relevant to waste disposal facilities and contaminated land;
- Effects of chronic exposure on plants and animals; and
- Cross-cutting theme: model testing, scientific robustness, uncertainty.

The programme also aims to create a long-term sustainable network through capacity building.

There are three different sub-programmes, TREE, LO-RISE and HydroFrame. LO-RISE, LOng-lived Radionuclides In the Surface Environment, may be of particular interest for BIOPROTA, having a focus on radionuclides such as uranium, radium and C-14. HydroFrame is focused on hydromechanical and biogeochemical processes in fractured rock masses in the vicinity of a geological disposal facility. TREE is focused on transfer, exposure and effects and aims to integrate the science required to underpin radioecology assessments for people and wildlife and to reduce uncertainties in assessments. Again, capacity building is a key component.

TREE is comprised of a number of different work packages:

- WP1: Biogeochemical processes and radionuclide behaviour in soil-plant systems, which is focussed on I-129, Se-79, Tc-99 and uranium in soils. The objective is to investigate whether short-term column experiments on the equilibration of radionuclides can be used by models can be used to match field conditions. Models will be developed to rpr3esent the time

dependent distribution of radionuclides between available and inaccessible forms with rate coefficients. Samples will then be taken from the Chernobyl exclusion zone to test the models with batch experiments being performed that are then validated against the field data.

- WP2: Novel approaches to estimate radionuclide activity concentrations in the human foodchain and terrestrial and aquatic wildlife. It is recognised that radionuclide transfers are often very simplistic and that an improved approach is required that can cope with the site specific nature of transfers and to enable extrapolation, with some confidence, between organisms and radionuclides where data gaps exist. RAPs will be sampled, along with soils and water, at a variety of sites and data used to investigate whether approaches (phylogeny & ionomics) from plant science can be used to improve models of radionuclide transfer to crop species and also to wildlife. Phylogency has been used to look at uptake relationships at one site and relationships used to predict concentrations in biota. A good linear relationship has been observed, suggesting the approach could be used to address data gaps for many organisms and radionuclides.

- WP3: Exposure of wildlife under field conditions. The objective of WP3 is to evaluate uncertainties in wildlife exposure estimation by assessing how animals utilise contaminated environments, using the Chernobyl contaminated zone as a study area. Camera traps, TLDs and GPS collars and faecal measurements will all be employed as a means of investigating habitat utilization by animals. Currently, the focus of activities is on selecting which animals to target. 50 camera traps are about to be deployed to identify common species in the study area.

- WP4. Mechanisms of biological effect and trans-generational impacts of exposure to ionising radiation. The objective of WP4 is to determine whether low level chronic exposure to radiation has significant effects on exposed populations in contaminated sites. A research facility is being built at the University of Stirling that will allow terrestrial RAPs (earthworms, bees etc.) to be irradiated in the DCRL range of exposure to allow gaps in effects data, associated with DCRL bands to be evaluated. A range of different endpoints will be studied and studies on aquatic species are also planned. The output is intended to provide data as input into improving benchmarks, develop an improved understanding of the biological mechanism for radiation effects, and to test the ICRP DCRLs.

5. THE 2014-15 BIOPROTA PROGRAMME AND FORUM ARRANGEMENTS

Arrangements for the continued organisation of the BIOPROTA forum, based on feedback from the sponsoring committee meeting are presented below and the planned and developing work programme is presented. Additional suggestions or proposals for project areas to be taken forward are invited.

5.1 FORWARD WORK PROGRAMME

A number of work programmes, in the form of focussed workshops, have been suggested for the 2014-15 BIOPROTA work programme and further project ideas are proposed for consideration by participant organisations.

5.1.1 Representation of environmental change in the near-surface environment

A workshop on 'Representation of Environmental Change in the Near-Surface Environment' organised to take place in the days immediately following the annual workshop.

Post-closure assessment of radioactive waste disposal takes into account the distribution of radionuclides and other contaminants potentially released from underground into the surface environment, or biosphere. Previous activities within BIOPROTA have examined processes relevant to contaminant transfer in the geosphere biosphere subsystem, leading to production of a generic methodology for how to address those processes. Work within the IAEA's MODARIA WG6 has in parallel been updating methods for addressing environmental change, with a focus in climate driven changes. Both activities have drawn on the results of previous work and the site and project specific level, as well as the results of the IAEA EMRAS II WG3 report that considered different approaches to dose assessment under environmental change. A further factor to be taken into account is the range of future human actions that may need to be taken into account within an assessment.

The objective of the workshop is to provide a forum for discussion and review of all the above activities with a view to developing suggestions for how all these different factors might be considered together in the Representation of Environmental Change in the Near-Surface Environment. The output of the workshop could potentially be used as the basis for undertaking an update to the IAEA-BIOMASS-6 methodology.

5.1.2 Managing correlations in selecting parameter values

It is recognised that some assessment parameters are correlated (e.g. Kd and CR) and, in order not to select or sample meaningless combinations of parameter values, this issue of correlations needs to be addressed.

For some key radionuclides there is quite a good understanding of behaviour to allow correlations in assessment parameters and assumptions to be evaluated, but this is not the case for all. The idea of undertaking a project on correlations for long-term assessments has been raised previously and anyone with suggestions on how to take this forward is encouraged to contact the technical secretariat who will assist in developing a work programme.

5.1.3 Next steps with C-14

From the C-14 workshop in Aix-en-Provence (see section 3.2), a number of possible future tasks were identified that may allow C-14 models to be further tested and/or developed.

For the terrestrial environment, a number of data sets have been identified that may potentially be available and that could be used to further test models. Data sets include the AECL Duke Swamp site and the data currently being published from the University of Nottingham field studies performed on behalf of RWM. Furthermore it was suggested that a model-data, model-model intercomparison performed by IRSN and SSM using IRSN monitoring data from a field site near Cape de la Hague could be extended to other interested participants. Interest has also been shown around developing an improved understanding of the effects of climate change on the cycling of carbon in soils and sediments.

For the aquatic environment, less work has been done to date by BIOPROTA as compared with that undertaken for the terrestrial environment. It was therefore suggested that it may be appropriate to undertake a detailed review of carbon pools in aquatic systems and food web and habitat interactions. A further task could be to apply available models to a case study around a well characterised lake, such as the SKB carbon balance data for Swedish lakes around Forsmark.

It has furthermore been suggested that there may be merit in undertaking a review of mire data with respect to C-14 and carbon behaviour and linking this to climate considerations.

The technical secretariat is continuing efforts to obtain data sets that could be used in forward activities and, based on interest expressed to date, will develop work programme proposals where appropriate data are identified.

Additional suggestions for the forward programme and/or proposals are invited.

5.1.4 Comparison of Assessments for Long-term Radioactive and Hazardous Waste Disposal

A follow-on workshop to that held in Slovenia in May 2013 on ‘scientific basis for long-term radioactive and hazardous waste disposal assessments’ (see section 3.4) has been proposed. The workshop would be focussed on the comparison of assessments for long-term radioactive and hazardous waste disposal. Objectives could include:

- analysis of the differences in protection objectives and assessment endpoints for radioactive and other hazardous disposal;
- review of assessments made for chemicals in radioactive waste;
- development and trial application of toxicity indices that work for chemicals and radionuclides;
- analysis of the differences in protection objectives and assessment endpoints for radioactive and other hazardous disposal;
- practical problems in making common assessments for mixed hazardous wastes; and
- demonstration of long-term protection of groundwater resources.

NRPA have provisionally agreed to host the workshop in Norway. It is anticipated that the workshop would be held early in 2015.

5.1.5 Assessment parameter database

EnviroCase are planning to develop a parameter database for the purpose of advanced biosphere assessments. It is recognised that there are a number of databases available that provide various data that are useful in assessments, but a focussed database for long-term biosphere assessments could help to support continuous data acquisition and review. The database would not be limited to Kd and

CR data alone, but would aim to be comprehensive in terms of the parameters required for long-term safety assessments. The database would be developed with sufficient transparency to be useful for selecting and justifying data in assessments and careful planning and population of the database could also help in identifying cofactors when making well-informed decisions in data selection. A knowledge quality assessment tool could also be incorporated.

The development work is planned with both internal and external funding, but additional funds and technical support would allow the process to be prioritised and allow the outputs to be more widely available. Interest in the database should be registered with Ari Ikonen.

5.1.6 Model testing library

It was proposed that a model testing library could be developed. This would comprise a collection of readily defined and specified model intercomparison and validation exercises that would be available on-line. The library would provide an opportunity for people to run models according to a set scenario and to submit results to the data bank to allow comparison with other models that have been applied to the scenario.

5.1.7 Practical guide for field work

A further suggestion proposed by Ari Ikonen was to take further the initial BIOPROTA Theme 3 output to a more practical level through the development of a practically-oriented handbook to field sampling of the ecosystem in support of biosphere assessments. The handbook would be comprised of a collection of examples on how site characterisation or individual focussed studies could be planned. It would cover subjects such as:

- how to establish an effective site characterisation programme and how to manage it, based on existing guidelines etc. and recognising varying assessment contexts and requirements.
- What to sample in practice and examples of how, starting from planning of the sampling scheme taking spatial, temporal and within-strata (intra-type) variation into account. For example this could demonstrate how to move from GIS data to the selection of appropriate sampling plots.
- How to analyse and report the field data so that it would be useful input for assessments.

The handbook would be intended as a resource that could help guide site characterisation activities and could potentially also support long-term management of contaminated sites.

Interest in the development of this handbook should be directed to Ari Ikonen.

5.2 FEEDBACK FROM THE SPONSORING COMMITTEE MEETING

The annual sponsoring committee meeting was attended by 11 participants.

New potential members were discussed and their potential participation was welcomed[a]. Continued links with other organisations and international programmes such as MODARIA were noted to be of value and continued dissemination of reports and information to participant organisations by the Technical Secretariat was welcomed. Participants also expressed satisfaction with the progress with

[a] Since the meeting, the Korean radioactive Waste Agency (KORAD) and the Burnasyan Federal Medical Biophysical Centre (FMBC) have formally become members of BIOPROTA

BIOPROTA activities in 2013-14. Further development of the BIOPROTA website has been suggested to allow for restricted areas to be made available for the distribution of draft material and the ability to include such a capacity will be investigated. Continued publication of BIOPROTA output in the scientific literature is encouraged.

5.3 FORUM ARRANGEMENTS FOR 2014-15

Danyl Perez-Sanchez from CIEMAT was confirmed as the new chairman of BIOPROTA for 2014-15. The work of Ray Kowe (RWM) in chairing the forum over the last years was gratefully acknowledged.

The next annual workshop is provisionally planned to be held in Madrid in May 2015. A poll will be organised to ascertain the preferred date for the majority of participants. Suggestions will also be invited on a topic for a back-to-back workshop.

APPENDIX A. LIST OF PARTICIPANTS

Participant	Affiliation
Elena Abarca	Amphos21
Lydia Morche	BfS
Danyl Perez-Sanchez	CIEMAT
Beatrix Lourino Cabana	EdF
Elsa Vitorge	EdF
Lous Le Tarnec	EdF
Juergen Hansmann	ENSI
Ari Ikonen	EnviroCase
Candida Lean	Environment Agency
Graham Smith	GMS Abingdon Ltd
Takashi Nakamura	JANUS (for JGC)
Trevor Sumerling	LLWR Ltd
George Shaw	Nottingham University
Sinae Shibutani	NUMO
Neale Hunt	NWMO
Anne-Maj Lahdenperä	Saanio & Riekkola Oy
Kirsi Riekki	Posiva
Tuomas Pere	Posiva
Neil Higgins	Public Health England
Laura Limer	Quintessa
Karen Smith	RadEcol Consulting Ltd
Nick Thompson	RWM
Ray Kowe	RWM
Simon Norris	RWM
Jordi Vives i Battle	SCK.CEN
Eva Andersson	SKB
David Copplestone	University of Stirling