BIOPROTA

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

Report of the Thirteenth BIOPROTA Workshop

Hamilton, Canada
18-19 June 2011

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PREFACE

This report was produced within the international collaboration project BIOPROTA.

BIOPROTA is an international collaboration forum which seeks to address key uncertainties in the assessment of radiation doses in the long term arising from release of radionuclides 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 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 annual BIOPROTA workshop, hosted by NWMO in Hamilton, Canada from 18 to 19 June 2011.

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 report prepared by Eden Nuclear and Environment with initial review by GMS Abingdon. Distributed 29 July 2011 to workshop participants for comment.

Version 2.0: Final report prepared by Eden Nuclear and Environment to address participant review comments. Distributed 14 October 2011.

CONTENTS

1. INTRODUCTION

The thirteenth BIOPROTA workshop was hosted by the Canadian Nuclear Waste Management Organisation (NWMO) in Hamilton, Canada on 18-19 July 2011. The workshop was held in parallel to the ICRER Conference at which a number of on-going BIOPROTA project presentations were made, including:

- Improving confidence in long-term dose assessments for U-238 series radionuclides (Oral);
- Gaps and uncertainties relating to Ra-226 behaviour and approaches to modelling transport in biosphere assessments (Oral);
- Studies on the retention of Se-79 in soils and uptake into plants (Oral);
- Non-human biota assessments for geological disposal facilities – A study of the key uncertainties and importance for dose estimates (Oral);
- A Comparison of Models for Assessing the Radiological Impact of ^{14}C Released to Soils in Gaseous Form Following the Geological Disposal of Solid Radioactive Wastes (Oral poster);

In light of this, detailed presentations on these projects was not included within the BIOPROTA workshop with only brief updates being provided for those unable to attend the conference.

This report provides a record of the presentations made and resultant discussions during the workshop.

The support of NWMO in the organisation and hosting of the workshop is gratefully acknowledged.

1.1 CURRENT SPONSORS OF THE BIOPROTA COLLABORATIVE FORUM

Currently there are 18 sponsors of the International BIOPROTA collaborative forum:

- Andra, France
- BfS, Germany
- CIEMAT, Spain
- EdF, France
- EPRI, USA
- IRSN, France
- JGC Corporation, Japan
- KAERI, Korea
- LLWR, UK
- Nagra, Switzerland
- NDA (RWMD), UK
- NRPA, Norway
- NUMO, Japan
- NWMO, Canada
- Posiva, Finland
- SCK.CEN, Belgium
- SKB, Sweden
- SSM, Sweden

In addition to sponsoring organisations, the following are recognised as academic (non-funding) members:

- Norwegian University of Life Sciences (UMB), Norway; and
- Oregon State University (OSU), USA.

1.2 OBJECTIVES OF THE THIRTEENTH WORKSHOP

The objectives of the workshop were to update interested parties on progress since the last meeting in May 2010 on the various activities and projects supported through BIOPROTA and to provide a forum for continuing exchange of information and discussion about additional topics of interest. It was intended that discussions would highlight continuing areas of common interest upon which future BIOPROTA tasks could be built. The meeting therefore focused on progress to date and implementation of a future work plan.

1.3 PARTICIPATION

The workshop was attended by 19 participants from 11 countries, representing a range of operators, national safety authorities and regulators and technical support organisations. Participants are listed in Appendix A.

1.4 REPORT STRUCTURE

The remainder of this report provides:

- An overview of progress made in 2010/11 (Section 2);
- A summary of presentations made by participants on their biosphere programmes, including challenges faced (Section 3);
- An overview of parallel working groups (Section 4);
- A summary of interest areas that could form the forward programme (Section 5); and,
- Forum administrative issues (Section 6).

2. PROGRESS IN 2009/10 OF ESTABLISHED BIOPROTA WORK PROGRAMMES

In 2010, a project on non-human biota sensitivity analysis and knowledge quality assessment was completed. This project was presented at ICRER and a separate overview within BIOPROTA was not made (see the 2010 workshop report for an overview of this project). A number of additional projects have been significantly progressed in 2011 and information on the status of these projects is provided below.

2.1 C-14 LONG-TERM DOSE ASSESSMENT (PHASE 2)

Laura Limer presented.

Interest in C-14 within BIOPROTA has been on-going since 2005. A 2009 report on the subject of modelling C-14 uptake into plants showed a large variation in model results. As such, a more focused project has been undertaken that looks in more detail at the processes of importance. The project has included a FEP analysis and the development of a conceptual model (interaction matrix) and the application of models to a two scenarios (gas release and groundwater release) to allow for quantitative model intercomparison. The status of the project is that a draft final report has been prepared and is currently under review.

For each model scenario, participants were requested to evaluate concentrations of C-14 in soil, plant and atmosphere. Consistent with the previous Cl-36 project, 4 crop types were considered – root vegetables, green vegetables, cereals and fruit. In order to investigate the factors that influence the canopy atmosphere, which is critical for C-14 uptake, different field sizes were considered.

There has been considerable debate within the working group on the meaning of 'fetch'. For some models 'fetch' is a relationship between the field length and wind speed / direction whereas for others (e.g. Andra), an alternative definition of fetch is given which can lead to a difference in units:

Model	Factors taken into account for calculating plant canopy atmosphere C-14 concentration				
	Wind speed	Crop Height	"Fetch"	Fetch definition	Fetch units
Andra	Yes	No	Yes	$\frac{length \times height}{volume}$	m^{-1}
Avila and Pröhl	Yes	Yes	Yes	$\sqrt{Area/\pi}$	m
EDF (Sheppard approach)	Yes	Yes	Yes	Length parallel to the wind direction [Amiro et al., 1991]	m
EDF (Respiratory approach)	The canopy concentration depends upon a recycling index, which itself was determined from experiments in which the crop height and field size varied. Thus there is some implicit dependence upon the crop height and a parameter relating to the field size.				
LLWR	Yes	Yes	No	N/A	N/A
NDA RWMD Biosphere Tool	No	No	No	N/A	N/A

For the gas release scenario, cereal C-14 concentrations varied by three orders of magnitude, which largely results from the approaches employed to model uptake by plants from the plant canopy atmosphere. The LLWR model has two canopy air layers such that the lower canopy is effectively closed leading to higher C-14 concentrations. The upper layer is more turbulent giving rise to greater mixing. For models with two air layers, the plant uptake assumptions (i.e. which air layer plants obtain C-14 from) can have a large effect on the plant concentrations calculated. If C-14 concentrations in the plant canopy atmosphere are fixed, the calculated plant concentrations for each model are similar (within 1 order of magnitude).

The main uncertainty in modelling C-14 uptake to plants relates to how quickly C-14 is released from the canopy atmosphere and is therefore no longer available to plants. It is intended that the effect of different plant heights and canopy densities will be investigated.

It has not been possible to address all uncertainties in the modelling of C-14 uptake into plants in order to build confidence in the appropriate modelling assumptions to use for an assessment. However, there are other work programmes that may help address some issues:

- The NDA RWMD has an experimental programme that aims to bound uptake assumptions for plants and provide data for the validation of models; and,
- SSM are undertaking a separate review of models for C-14.

Discussion

The output from the project may be important in relation to a number of organisations with C-14 wastes (e.g. arising from decommissioning of graphite moderated reactors): uncertainties relating to the rate of release from the near field (affected by waste packaging and form of C-14 in the waste), combined with uncertainties in biosphere assessments, effect the determination of the most appropriate means for providing containment in disposal.

A key uncertainty for biosphere assessments relates to the amount of microbial activity in soils to allow for conversion to CO_2 if methane is the form of C-14 released from a facility. The influence of microbial activity on dose calculations has been considered within the project through variant calculations that assume methane to CO_2 conversion rates ranging from 10% to 100%.

2.2 REFERENCE APPROAPCH FOR HUMAN INTRUSION EVENTS INTO DEEP GEOLOGICAL DISPOSAL FACILITIES

Graham Smith presented.

This project is focused on why and how human intrusion (HI) may occur and how this would lead to radiation exposure to those involved, including identification of the processes that constrain uncertainty. The scope includes inadvertent HI only and disposal at depths greater than 50m. The output will be a documented reference approach that addresses relevant IAEA / ICRP assessment criteria. Different waste types (HLW / ILW), geological environments and engineered barrier systems are being considered such that the output should be applicable to multiple sites and deep disposal conditions without becoming so imprecise that it is no longer useful. No assessment time limit is set, but it is intended that the method will allow the dose implications of HI at different times to be evaluated; as such some illustrative examples will be provided.

The IAEA SSR-5 (published in April 2011) sets a dose constraint of 0.3 mSv/y for a single disposal facility; however, this only applies to natural events. Guidance for HI is as follows: if a given scenario results in a dose below 1 mSv/y to those living around the site then further efforts to reduce the

probability or consequences are not warranted. If above 20 mSv/y then alternative disposal options should be considered. If calculated doses fall between these values then reasonable efforts would be warranted during facility development to reduce the probability or limit the consequences, i.e. optimisation. These dose criteria apply to those living around the site – those involved in the drilling activity are apparently not included.

Both the IAEA and ICRP call for consideration of plausible stylised scenarios (e.g. ICRP 81 and IAEA SSR-5). National requirements are similar although there are differences in the details between different countries.

Previous assessments have considered impact on those directly involved in HI, but also consequences for radionuclide migration from a facility resulting from changes to groundwater flow systems, changes to groundwater chemistry or the generation of a permeable flow path to the surface. For hard-rock scenarios, the focus is largely on drilling (direct penetration of the facility and the consequences arising from bringing material to the surface)[a]. For soft-rock disposal, additional scenarios have been considered, including salt mining. Past assessments have not taken into account details of different drilling techniques and related human activities at the site.

Based on the review of past HI assessments, it was decided that the most appropriate focus for the project would be dose consequences to those directly involved in HI and those affected by material brought to the surface. Drilling is the main intrusion mechanism since this is considered the most likely reason for intrusion. Consideration is being given to periods of institutional control and the time over which knowledge can reasonably be retained. Different drilling techniques and human activities at the site are being taken into account; a review of drilling techniques has been undertaken to identify the type of drilling that could occur at different depths in different geologies and the duration over which drilling may occur and how material would be brought to the surface (e.g. core / drilling fluid). This has resulted in the generation of a matrix of scenarios and dose pathways. In total, 50 scenarios have been identified. The different scenarios are bounded to ensure they are plausible by taking account of drill diameter versus depth.

A workshop was held in Stockholm, hosted by SSM, in April where the project approach and initial results were presented and discussed. One aspect that came out of the workshop was that, for material brought to the surface and left at the drill site, previously justified clearance levels for contaminated land, which involve a wide range of exposure scenarios, could be applied to assess individual doses rather than undertaking another new set of assessments.

Calculations have been undertaken for the different plausible scenarios based on unit input that will allow results to be multiplied up for particular waste streams. In undertaking calculations, some shorter-lived radionuclides have been included as a means by which it can be demonstrated that activity (and hence risk) reduces over time. Heterogeneity of the waste is also recognised as a factor requiring consideration as well as information on particle size and chemical form on dose coefficients.

The next version of the report is due at the end of August and will be distributed for further review. Comments that have been received to date on the approach and initial output are being taken into account and revised calculation output is being produced. Illustrative examples of the application of the approach will be provided based on ‘order of magnitude’ calculations for HLW and ILW waste streams. Radionuclides of particular interest will be highlighted.

[a] In discussion it was noted that in Canada there is a legal requirement for gamma logging of cores resulting from the drilling of deep boreholes. This requirement must be met before any license will be granted.

Discussion

In Sweden, a scenario is considered by which the repository remains open and floods. Contaminated flood water is then extracted. This has not been included to date in the project, but it was acknowledged that it should be noted.

Doses from early intrusion, while high, would still be lower and much less likely to occur compared to leaving the waste on the surface, where it would be more likely to be disturbed should there be a loss of societal control. This is an argument for disposal.

Since the output is based on unit activity concentrations, it was noted that it could be applied to evaluate dose implications associated with drilling into uranium ore deposits.

2.3 DEMONSTRATING COMPLIANCE WITH PROTECTION OBJECTIVES FOR NON-HUMAN BIOTA DOSE ASSESSMENTS

Karen Smith presented.

In recent years, numerous NHB assessment methods have been developed to allow environmental consequences of conventional releases of radioactivity to be assessed. These methods are largely associated with some form of numerical criteria that are used as a means of screening low risk activities rather than trigger regulatory action. There are currently no internationally agreed environmental benchmarks relating to 'unacceptable risk'. In the absence of such benchmarks it is difficult to evaluate the need for risk management such that breach of a screening level largely triggers more detailed assessment with the objective of driving dose calculations below the screening value.

Assessments for geological disposal facilities introduce further difficulties. Assessments are based on hypothetical subterranean release scenarios (whereas methods are largely derived for releases from the surface to the surface) and focus on long-lived radionuclides for which there is often limited data on environmental transfers and the period of peak discharge varies. Further issues relate to the focus of protection – what plants and animals will be present in the distant future? No international guidance on suitable approaches for demonstrating compliance is currently available that can be applied to such assessments. Where screening values for such assessments are exceeded, there is limited scope for undertaking more detailed assessments such that the interpretation, as much as the dose calculation, forms part of the overall assessment. In recognition of this, a project was initiated in 2010 with the objective of developing a more structured approach to dealing with situations in which current screening criteria are breached. This was to be achieved by investigating approaches that could be taken to demonstrate compliance in situations where screening levels are exceeded. The output of the project is intended to support those currently undertaking assessments of the long-term impacts on the environment from geological waste disposal and also to provide input to the international debate on environmental benchmarks for radiation.

Different methods are available for deriving protection criteria, all of which have been applied variously in national and international programmes:

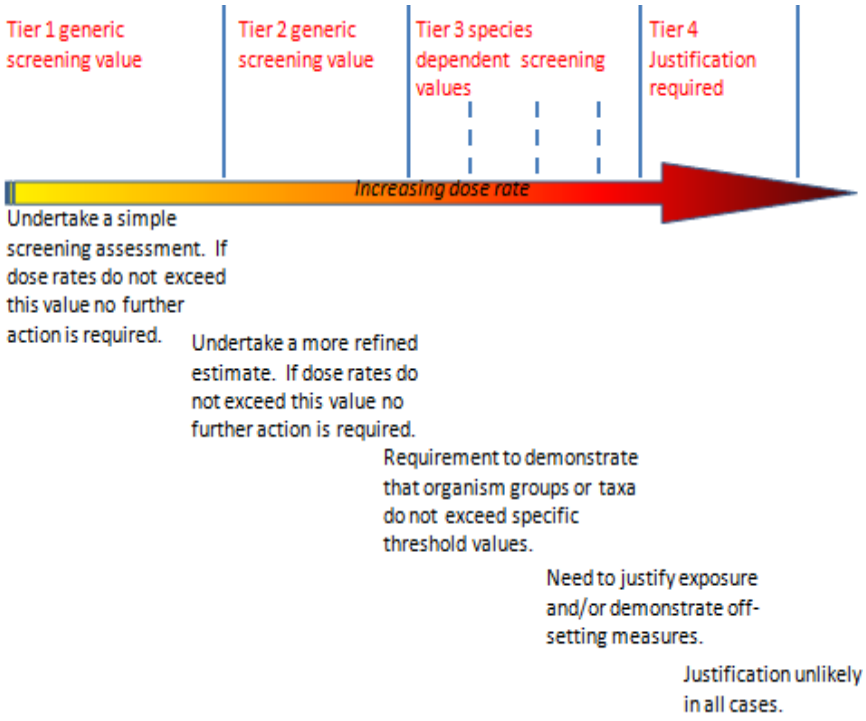
- Expert judgement[a]
- Comparison with natural background

[a] May be applied as a sole means of deriving criteria. However, an element of expert judgement is common to all approaches.

- Assessment Factor approach
- Species Sensitivity Distribution (SSD)

The majority of the criteria derived to date are generic (i.e. they apply to all species or all species within a particular ecosystem). However, it is largely recognised that there is variability in the radiosensitivity of different organisms and it is often the least radiosensitive organisms that are the limiting factor in assessments.

Based on a review of current approaches, an initial concept was developed for presentation and discussion during an initial project workshop at Herrankukkaro, Finland in March. The workshop was attended by 12 participants representing operators, regulators and researchers. The concept is summarised in the figure below.

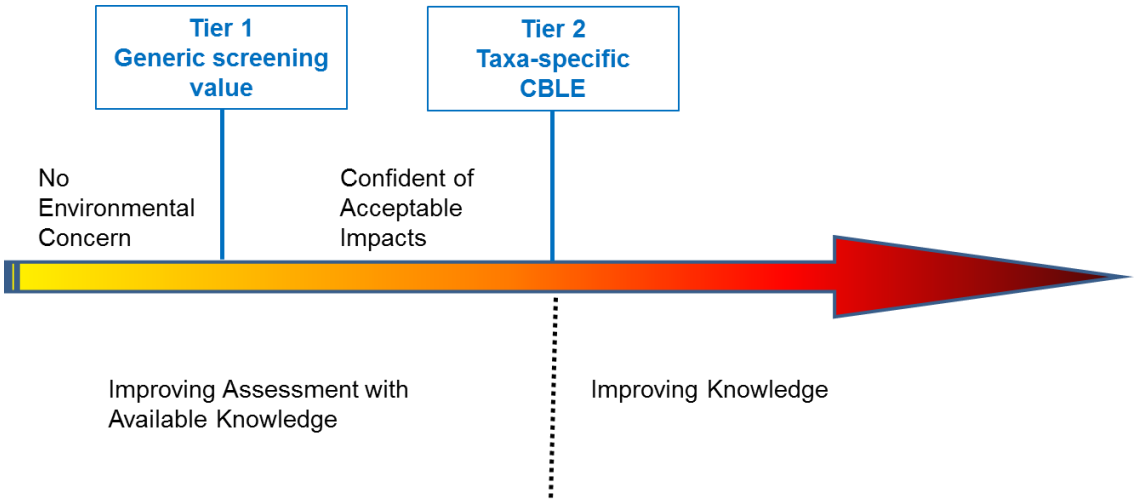


Conclusions from discussions during the workshop were that:

- There is a preference for multiple 'groups' of organisms (e.g. taxa) to be used as the basis for developing further assessment criteria, but that delineation by ecosystem not justifiable (for example, why would a frog in freshwater be more or less radiosensitive than a frog on land?). On this basis, the following groupings (based on considered availability of data) were selected.
    - Vertebrate
    - Invertebrate
    - Higher plant
    - Lower plant (e.g. phytoplankton)

- In relation to the number of 'criteria' and the terminology that should be used, it was agreed that:
    - 'Screening value' was acceptable and should represent a simple assessment requiring limited resources with the value being set to represent 'no environmental concern'. Assessments above this value should indicate a need for some form of action.
    - A second level criterion should then be used that represents a limited (acceptable) effect level and should be derived for different taxa. The term Confidence Based Limited Effects Level (CBLEL) was derived.
- Of the methods available for deriving criteria, SSD was the preferred approach, but it was acknowledged that this is data intensive and there may be insufficient data upon which CBLEL values could be derived at this time. As such, a 'taxa-multiplier' approach was considered a suitable way forward. This could be based on the relative radiosensitivity of broad taxonomic groupings and applied in conjunction with derived generic screening values (i.e. tier 1). The advantages of this interim approach were considered to be transparent and traceable application and ready adaptability to national regulatory requirements.

The initial concept was therefore revised, in light of discussions at the workshop, to:



Assessments falling below the tier 1 screening value would require no further assessment. The zone between tier 1 and tier 2 (CBLEL) would be representative of limited (acceptable) impacts. Assessments within this zone should make use of available knowledge to improve assessments (e.g. application of more refined models or use of more site-relevant radioecology data). Above tier 2 there would be an increasing likelihood of unacceptable impacts such that there may be a requirement to refine assessments through deriving new knowledge (e.g. radioecology research to derive parameters for which large uncertainties exist) or through repository design considerations. The need to justify the development would increase within this zone.

The output from the initial workshop and feedback from the workshop report are being used to further develop and refine the concept. A second workshop was held subsequent to the BIOPROTA workshop in Glasgow in July and the results from discussions at this workshop will be used as input to the project report, which is due to be distributed in draft form toward the end of August for comment.

Discussion

The need for a screening value in addition to the CBLEL values was questioned. The driver behind the use of both values is to enable a very resource efficient, yet conservative assessment to be taken initially that could effectively rule out the need for more resource intensive work to be undertaken. As the assessment then becomes refined through the application of greater resource levels, the CBLEL values, which are less conservative than the tier 1 screening value would be applied.

2.4 MODELLING THE U-238 DECAY SERIES

Danyl Perez-Sanchez presented.

The U-238 series project is focused on the upper part of the decay chain (uranium – thorium – radium) and behaviour in soils and uptake into plants. The plan was to develop an interaction matrix to link the key FEPs of relevance and then to undertake model inter-comparison exercises – one hypothetical and one based on a real site. A review of the main features relevant to the behaviour of the different radionuclides was also undertaken.

Uranium in soils occurs in different valences with +4 and +6 being the most important. Being redox sensitive, there are a number of factors that must be taken into account when considering behaviour in soils including soil mineralogy and heterogeneity around this, pH etc. Radium has a high affinity for regular exchange sites of soils such that organic matter sorbs around 10 times more radium than clay. Radium is not easily complexed.

In the case of uptake and translocation within plants, there is limited information available but a large range in soil to plant transfer factors is evident (for radium the range covers 7 orders of magnitude). Within the IAEA compilation of transfer factors (TRS 472), little information is provided in relation to soil properties for the values given that would assist in selecting the most appropriate value for a given site.

For the intercomparison exercise, 4 models are being applied (the Thorne model developed for CIEMAT, SAMM (Andra), NDA RWMD biosphere assessment tool and SYVAC3-CC4 that is used by NWMO). Each model has been audited against identified FEPs.

The CIEMAT model uses a redox (hydrology) approach where the water content of different soil layers governs radionuclide movement. The hydrological regime in Spain is very different to other countries and this was the driver for the development of a hydrological model.

The NDA RWMD model uses two soil layers whilst one soil layer is included within the NWMO model. The SAMM model has, like the CIEMAT model, multiple soil layers, but movement of radionuclides is governed by diffusion and advection rather than soil hydrology.

The hypothetical scenario considered high and low precipitation conditions whereas the real scenario was based on a site in Spain (Las Ratones) that has been used for research such that there is a good quantity of data available to support the modelling study. However, measurements are not time-series data, but rather single point values and the site-specific information has been applied differently between the models. Different assumptions regarding source term have also been applied. As such that there is a need to better define the scenario to focus parameters such that differences in models can be more readily evaluated.

Model approaches are becoming more and more complex, but one issue that comes to light is whether there is adequate data to support such developments. Consideration also needs to be given as to whether background for uranium series radionuclides should be included in long-term

assessments. Future work on U-238 series radionuclides may focus on more than just soil to plant pathways (for example inclusion of inhalation pathways and/or implications for non-human biota). There is also the potential to progress the study to other radionuclides within the decay series.

Discussion

SKB have looked in considerable detail at radium and have derived data for a range of soils and ecosystems. The derived data is very different from that given in TRS472 and is of much lower variability. SKB data will be made publicly available in an SKB report.

For the Spanish site, a lot of material has been extracted from the deep geosphere to the biosphere and variability in the content of uranium within the extracted material may explain some of the differences observed in the site-derived data.

2.5 SE-79 IN THE SOIL-PLANT SYSTEM: APPROACHES TO MODELLING

Karen Smith presented.

Phase 1 of the Se-79 project (which completed in 2010) investigated the features, events and processes of importance for governing selenium behaviour in soils and uptake into plants and a conceptual model (interaction matrix) was developed on the basis of this review. Overall, soil redox was identified as the key aspect in determining Se behaviour in soil. However other aspects were also of notable importance, including:

- pH;
- Soil mineralogical and chemical composition;
- ionic composition; and
- microbial activity.

The objectives of phase 2 have been to investigate the degree of model complexity required for Se-79 soil-plant models through the application of different models (conventional and new approaches) to hypothetical release scenarios. Such an approach is intended to provide a qualitative and quantitative mechanism for exploring the significance of different models and data assumptions.

Results from the application of models to the derived scenarios (groundwater release and irrigation) were due in January 2011. However, errors in the application of two of the models to the scenario resulted in delays. Nonetheless, these delays have resulted in additional participation in the project (IRSN) and all results have now been received. These results will be analysed in July / August with a draft report being circulated for comment by the end of August. Further discussion on processes of importance to selenium modelling is also anticipated during the BIOPROTA workshop on the Behaviour of Redox Sensitive Radionuclides in the Geosphere-Biosphere Interface Zone, which is to be held in Belgium from 6-8 September.

3. CHALLENGES IN RADIOACTIVE WASTE MANAGEMENT AND BIOSPHERE ASSESSMENTS

The following sections provide an overview of the presentations provided by the various participants on their radioactive waste management and biosphere assessment programmes.

3.1 OVERVIEW OF NWMO ACTIVITIES

Paul Gierszewski provided a welcome to the workshop on behalf of NWMO and presented an overview of activities being undertaken.

In Canada, around 15% of electricity is generated as a result of nuclear power production. The current waste strategy is on-site storage with most L/ILW being stored at a central reactor site and spent fuel being either wet or dry stored at each reactor site.

NWMO (a not for profit organisation) was created as a result of the Canadian Federal Act in 2001 and is responsible for the long-term management of nuclear fuel. There are two main projects underway. The first is an adaptive phased management project for spent fuel. The recommendation has been for deep geological disposal in crystalline or sedimentary rock within a willing host community. The disposal process consists of a staged process that includes discussion with communities. As such the process must be flexible to adapt to community requirements. To date, nine communities have expressed a formal interest in learning more and an initial assessment of the geology in each of the community areas has been completed based on available geological information. Feasibility studies have been completed for around 50% of the sites and one has been identified from these as having an appropriate geology.

The second project is Ontario Power Generations proposed Deep Geological Repository project for low and intermediate level waste. The project is focussed on the site that currently has the majority of the waste. It is proposed that disposal would be at a depth of 680m in argillaceous limestone. It is acknowledged that such disposal is not required for the majority of LLW; however there is long-lived ILW to be managed and, as such, one solution is being sought for both waste forms. OPG have contracted NWMO to prepare the license application. Once the license is granted, OPG would then take over the operation of the facility. It is anticipated that the application will be a 2 year process with a resultant operation date around 2018.

Further information on these projects is available from www.nwmo.ca/publications and www.opg.com/dgr.

3.2 SOIL KD AT FORSMARK

Steve Sheppard presented.

A project has been undertaken to measure site specific Kds of indigenous elements from field soils around the SKB Forsmark site (SKB report R-09-27). Field soils from the SKB site have been sampled and water extracted by incubation and centrifugal procedures (i.e. soils were not dried) to enable radionuclides to be measured that are representative of equilibrium conditions. In total 3 clay and 2 peat soils from two depths (22 cm and 52 cm) have been analysed and relevant soil properties measured. Some plant, till and sediment samples have also been analysed.

The hypothesis being tested was whether or not site geomorphology is relevant. There was a reasonable range in the properties of the five soils considered (OM content and pH).

Particular points of note arising from the analysis are as follows:

- Clay gyttja are derived from marine deposits and are quite acidic whereas other clay samples were of a higher pH. Peat soils were of medium to low pH.
- Manganese was bimodal on a frequency histogram and this is thought to relate to redox although soil anoxia could account for this. Further consideration is therefore required.
- The presence of sulphides in the marine-derived clay gyttja soil can lead to metal sequestration, resulting in perceived high Kd's. This can be affected by redox conditions.
- There would be a residual field effect on soil redox, however there is also potential for a redox effect to occur in the laboratory and this requires consideration.

Results of the analysis have been compared against soil properties. A trend was evident between pH and Kd for manganese whereas for uranium the opposite was observed such that Kd is inversely related to pH. For radium, Kd increased with increasing pH in clay soils but this relationship was not observed in the marine derived soil. Overall, pH appears to be a key factor influencing Kd.

When looking at uptake into plants, the concentration ratio of root crops versus seed crops showed a 1:1 relationship with the exception of rare elements which are known to absorb onto roots. Some adherence onto leaves was also evident. A negative correlation between Kd and CR was evident as expected, but differences were noted between plant essential and non-essential elements although differences were not as evident in SKB data compared with literature data.

Soil characteristics are key to identifying the appropriate Kd for a given soil and should therefore be derived in any analysis. pH is especially important and should therefore be prioritised.

Discussion

There is some concern as to whether it is appropriate to rely on site specific data for long-term assessments since the data set from site analyses is often limited or whether generic data would be more applicable since Kd has the potential to change over time (for example, caesium is known to accumulate in soil interstitial layers such that Kd can vary over periods of decades. It can therefore be argued that even with site (or indigenous) data there is still a need for generic data.

3.3 A REVIEW OF A C-14 MODEL USED FOR DOSE ASSESSMENT DUE TO RELEASES FROM NORMAL OPERATIONS IN SWEDEN

Shulan Xu presented.

A revised dose assessment from the Swedish nuclear power companies was submitted in 2001, which included a process oriented C-14 ($POM^{14}C$), which has been published in a scientific paper. The assessment was accepted with the exception of the $POM^{14}C$ model (the model had not been officially reviewed). In order to review the model attempts have been made by SSM to reproduce the results.

There are a number of different models available for C-14 that differ widely in complexity. Models generally employ either a photosynthesis and respiration approach or consider diffusion processes. Some use dynamic processes for carbon transfer within the plant and empirical data for plant growth rates; others consider dynamic growth rates based on light efficiency and temperature etc or a combination of these approaches. The $POM^{14}C$ model considers dynamic growth rates.

A model intercomparison exercise was conducted within EMRAS I that was based on experimental data as a means of verifying models; this considered 5 models in total. Large uncertainties were evident in the experimental data so the ability to draw firm conclusions was limited, but largely predicted concentrations were in agreement (within a factor of 10) with observed values. Based on these results it appears that all models could be applied to the given scenario.

The POM^{14}C model uses 7 equations to calculate the concentration in crops at time of harvest, but some issues have been identified in relation to how clearly model parameters have been explained. As such the approach employed by SSM differed slightly to account for some errors leading to differences in model output. If the parameters in the published paper are applied then results are different suggesting that quality assurance in the application of the original model was not sufficient. No sensitivity analysis has been undertaken to explore what are the key model parameters.

Overall it was concluded that the POM^{14}C can be applied reasonably well, but in the case of the application of POM^{14}C model the assessment would be more transparent and robust simply with an approach of use of known final yield to calculate ^{12}C concentrations in the crop, followed by calculation of the ^{14}C content from the average ^{12}C/^{14}C ratio in the atmosphere. A full paper of this review work is to be published in the proceeding of NSFS Conference Reykjavík 22-25 August 2011.

SSM now intends to undertake a thorough literature review of C-14 biosphere models. The applicability of different model approaches largely depends on the nature of the release being considered. For example, dynamic models are more applicable to pulse discharges where dynamics become interesting with regard to uptake (e.g. diurnal versus nocturnal release). For example, the STAR C-14 model (included within the EMRAS I intercomparison exercise) was developed for UK sites to assess the implications of short term releases and the differences in doses for day and night-time releases. The model allowed turnover of C-14 in crops to be considered (for example uptake by photosynthesis during the day and release at night as a result of respiration. Such complex models may not be warranted for long-term constant release scenarios.

3.4 UPDATE ON THE SKB PROGRAMME

Ulrik Kautsky presented.

A license application was submitted by SKB in March 2011 and is currently under review by SSM. The review process is anticipated to take a couple of years with review comments likely to give rise to further work requirements. After this, it is anticipated that a decision will be made around 2015 by the environmental courts; if successful construction would begin in the same year.

Various disposal methods were investigated in the SKB programme with KBS-3 being selected as the preferred approach. In this approach fuel rods are taken intact and placed within copper canisters that are then encapsulated in bentonite clay within bedrock. Forsmark was selected as the preferred site following preliminary site investigative works and dose assessments.

For risk calculations peak landscape dose factors (LDF) are used, but for site selection radionuclides reaching the biosphere over time was used as a means of evaluating the retention characteristics of the sites considered.

For the safety assessment a risk criterion of 10^{-6} for a representative person must be met, which equates to around 1% of the natural background in Sweden. The assessment timeframe, as stipulated in national regulations, is 1 million years.

The safety assessment has been reported in 3 volumes. The main safety assessment report is TR-11-01. The biosphere synthesis report (TR-10-09) is supported by a number of additional reports, all of which are available from the SKB website. Climate evolution is considered in TR-10-49.

The reference evolution of the repository takes into account climate cycling which takes account of the most likely climate development over time. Overall climate (temperature / precipitation) has only a minor effect on the repository itself, but glacier formation could result in canister collapse and could, ultimately result in earthquakes. The far-field and biosphere would also be affected by glacier development that could affect radionuclide migration (e.g. changes to groundwater flow and chemistry). Ice sheet development during glacial cycles has been determined on the basis of air temperature and consideration has then been given to how this would affect shoreline displacement / sea level. The past glacial period has been modelled and this then used to model the future. Alternative climate cases have been considered such as global warming.

Since the failure of canisters as a result of earthquakes is of concern, the canisters have been designed to take 5 cm shear and will not be placed within fracture zones that could be subject to a 5 cm or greater slip. Although there is a small risk of earthquakes at the site, the risk is alleviated by these design considerations.

Hydrology at the site has been modelled in relation to climate. When the repository is submerged below sea level there is an order of magnitude difference in groundwater flow rates when compared to the repository being land-based.

Within the biosphere analysis, the past and present have been used as a basis for considering what could occur in the future.

The release points from the geosphere to the biosphere will change with shoreline displacement. Modelling of the biosphere acknowledges that ecosystems are not separate entities, but are rather continuums such that one model is used for all ecosystems. The model assumes unit release to calculate LDF with peak values used in the assessment. The LDF are calculated for different climate states. Current climate conditions are the limiting case. The highest LDF is calculated for Ra-226. Sensitivity analysis has identified Kd in the lower regolith as one of the key parameters in terms of dose.

Whilst the license submission is under review, SKB are working on an extension to the LLW facility, SFR, which is planned for 2013. A new study is also looking at an ILW disposal site. Throughout, the research and development programme, including the SKB Greenland project, will continue.

Discussion

The question arose as to whether a repository could be directly affected by glacial erosion. Largely such erosion occurs to depths up to 6-12 m based on past glacial events. As such the importance of this scenario for deep repositories is limited. However, the effect on shallower disposal depths could be substantially greater.

A non-human biota assessment was required by the Swedish authorities. This was undertaken using ERICA, but with site-specific data where available. The assessment is reported in SKB report TR-10-08.

To identify human habits, the land area and availability of food (i.e. land productivity) has been used rather than trying to predict changes in human behaviour. The approach has required the areas of land affected by the repository to be identified.

3.5 BIOSPHERE ASSESSMENT FOR THE FINNISH REPOSITORY CONSTRUCTION LICENSE APPLICATION: CHALLENGES RAISED BY THE REGULATORS

Ari Ikonen and Thomas Hjerpe presented.

The planned Olkiluoto repository is for the disposal of spent fuel from the five current nuclear power plants in Finland, but also from a fourth planned Olkiluoto reactor.

Within the safety case, the biosphere assessment has been much more integrated than previous with respect the the methodology and especially the interfaces between the geosphere and the biosphere modelling to ensure commonality in approach and consists of the surface description, terrain and ecosystem development and models for surface hydrology and landscape.

A regulatory review of the preliminary construction license submission has identified a number of 'red light' issues that must be addressed before a construction license would be granted. Many of these relate to a lack of detail being provided (more traceability and transparency is required), but also some data gaps in transfer modelling and use of well water (including the assumed depth of a well) have been identified. The fact that only the base scenario was analysed was also criticised. However, based on discussions between Posiva and the regulator (STUK) there is confidence that these issues will be resolved for the 2012 license submission. 'Yellow light' issues have also been identified that must be resolved prior to an operational license being granted.

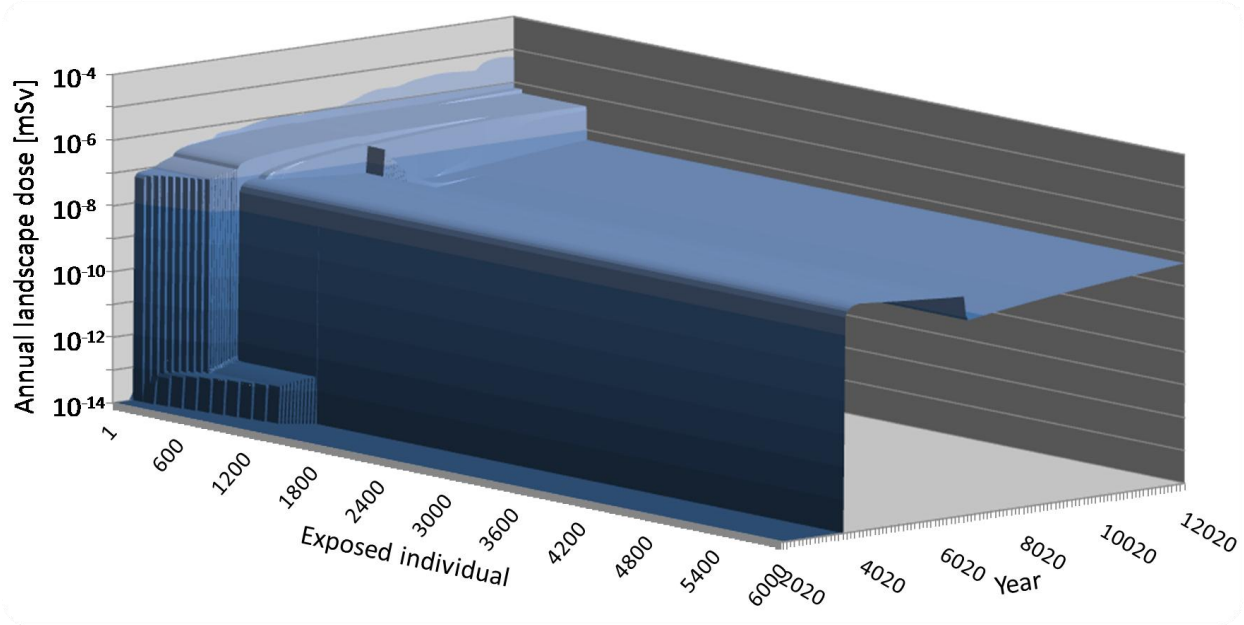
The types of scenarios that must be assessed in the safety case are stipulated by STUK and should include a base scenario and variant scenarios around this that assume substantially declined performance of safety functions. Disturbance scenarios are also required that take account of unlikely events or processes that may affect safety functions. However, the biosphere does not (and cannot) have a safety function. As such the base scenario has been set on the basis of key scenario drivers that are closely related to FEPs. Drivers are selected based on their potential effect on the surface environment evolution, subsequent migration of substances and level of radiation exposure to humans and the environment. The objective is to identify reasonable (credible) lines of evolution. A health based target (i.e. the level of radiation exposure to humans and the environment) is used for the base scenario and, rather than trying to predict human behaviour in the future, present day perceptions of human behaviour are being applied. The variant and disturbance scenarios are then used to identify uncertainties around the base scenario.

In identifying the base scenario a systematic approach has been applied. Those factors that can affect the evolution of the surface environment within the stipulated time period of several thousand years (interpreted by Posiva as 10,000 years) have been identified.

Ecosystem considerations are driven by sea level change, the hydrological balance and the effect of humans (mainly selection of resources and influence on climate). Once key drivers for development of the surface system have been identified (e.g. level of greenhouse gas emissions and use of local natural resources), a FEP analysis is undertaken.

The use of natural resources is tied to the type of landscape assuming that dietary profiles remain unchanged over time. A cautious assumption that all food is derived from the site is applied in line with STUK requirements. A representative people approach in line with ICRP 101 is used with the focus on lifetime doses to adults, consistent with the IAEA. The number of people that can be exposed is derived on the basis of land productivity, amount of land appropriate for residential areas and availability of drinking water. The key radionuclides of interest are I-129, C-14 and Cl-36 for the

reference case which assumes that radionuclide migration from an initially defective canister begins at 1000 years post closure. A regional assessment is undertaken which calculates annual doses to all people and, from this, the 20 most exposed persons are selected as the critical group. The dose end point for most exposed people is the average annual dose in the critical group. In addition, a local group is identified, limited by food production such that once all food from the region has been consumed, doses to additional persons are based on water consumption only (significant water consumption can only occur 3000 years from present as this is the first point at which a freshwater lake forms at Olkiluoto in the reference case. An example of the output from the biosphere assessment is provided below.



In relation to 'red light' issues identified by STUK, the following points were raised:

- STUK have not stipulated the amount of data gaps in site specific parameters (e.g. transfer parameters) that would be considered acceptable; as such more sampling and analysis is required to derive data, but not all data gaps can be filled. As such, site date will be combined with complimentary generic data (e.g. underlying TRS 472) to evaluate appropriate ranges from site data.

- There is a direct requirement to document the safety case carefully ensuring that justifications for the assumptions adopted are clearly given. To assist in clarity and transparency, two self-standing main reports will be produced that outline the biosphere description ("the scientific basis") and assessment synthesis ("the modelling"). Four key supporting documents will also be produced on databases, land uplift modelling, geosphere to biosphere interface and dose assessment modelling. These six reports will form the documentation needed for a reasonable level of repeatability, but certainly a large number of details of minor importance to the entirety of the assessment need to be left to a range of individual background reports.

Discussion

The highest annual dose calculated was around 10^{-5} mSv, based on realistic release predictions assuming a single canister failure. Variant calculations within the Posiva safety case will evaluate the consequences of, for example, multiple canister failures.

The presentation of the range of doses that could be received (the dose distribution, see the figure above) was considered beneficial in communicating the fact that not all persons within a population could receive the maximum calculated dose.

3.6 RADIOLOGICAL ASSESSMENT AND BIOSPHERE MODELLING FOR RADIOACTIVE WASTE DISPOSAL IN SPAIN

In Spain, there are both nuclear power plants and uranium production. The radioactive waste arising from activities are estimated at 200,000 m^3 of L/ILW and 10,000 m^3 of HLW/spent fuel.

Waste management is governed by ENRESA, which sets research and development plans every 3 to 4 years. The current R&D programme runs until 2013 and includes a requirement to maintain a watching brief on international thinking, maintain in house capacity, provide support to the waste storage projects. CIEMAT is the technical support basis for ENRESA.

Previously a nuclear power plant was dismantled with HLW being sent to France for reprocessing; however, this waste is to be returned to Spain in 2011. Consideration is therefore required as to what to do with this waste. HLW is currently stored in individual temporary storage facilities, but there is a desire for a centralised facility for temporary storage: no formal strategy for long-term management is currently available, but a decision is anticipated within the next 12 to 20 years. There are political issues relating to the location of a centralised facility

A disposal site for L/ILW is available at El Cabril, which has capacity for safe disposal until around 2020.

The work of CIEMAT is therefore to compile relevant documentation spanning from the IAEA Biomass programme to the current time on biosphere evolution and to look at what is on-going internationally. There are also radionuclide specific projects such as the development of conceptual models on the basis of available information for I-129, U-238 and Ra-226 (which includes working with international groups on these issues) and to develop biosphere models for redox sensitive radionuclides that are linked to the unique hydrological cycle within Spain. This latter work began with Se-79 and has now progressed to the U-238 decay series radionuclides. There is an intention to link redox models to irrigation models since there are large differences in irrigation practices throughout Spain.

An additional area of interest is the potential for the application of biosphere assessment methods and models to site remediation projects, including the remediation of a site affected by plutonium contamination arising from a US airplane crash. Radium radioecology research is also being carried out in Spain in relation to NORM and legacy sites. Much of this work was presented at the Ra-226 workshop in May 2010 and is summarised in the resultant workshop report.

Remediation of sites is being supported by prospective assessments. There is the potential for remediation activities at the various sites of interest to create new wastes that will be required to be managed.

3.7 CHLORINE BIOGEOCHEMICAL CYCLING AND STORAGE IN SOILS: CURRENT STUDIES AT ANDRA

Yves Thiry presented.

There are two key scientific programmes at ANDRA. One is dedicated to monitoring plots that are situated at the site of the future national repository; the other is focused on the treatment of radionuclide migration in the biosphere. For this latter programme, Cl-36 is a radionuclide of particular interest due to it being a major potential contributor to long-tern dose; it has a long half-life, high

solubility and mobility in the environment, low reactivity with biotics, is subject to isotopic dilution with stable chlorine in the geosphere and biosphere and is an essential element for biota. Considering its potential importance in long-term dose assessments, there is a lack of knowledge on transfer coefficients.

Modelling approaches at ANDRA include traditional transfer models that consider the flux between compartments and specific activity models that can be applied to the long-term chronic contamination of equilibrium systems. Work is on-going to look at the level of complexity required for radionuclide-specific models in order to increase understanding of the biogeochemistry (e.g. the residence time and speciation of chlorine).

Three studies have been carried out in relation to chlorine:

- Variability of organic and inorganic chlorine levels and pools in terrestrial environments
- Chlorination rate
- Chlorine cycling and modelling

The first study (chlorine levels and pools) focused on French forest sites. Around 50 sites were selected that reflected a gradient in chlorine deposition (decreasing from west to east) and a range of soils and tree species. By including such variability it was intended to investigate the effect of biomass production and turnover and transfer dynamics in soils with different humus levels.

The majority of chlorine was associated with humus when compared against litterfall and mineral soils, however there was a large degree of variation. The percentage of organic chlorine in fresh litter fall was low, increasing in humus and an even greater percentage was conserved in the mineral soil pool. Input of chlorine to the system was dominated by atmospheric deposition with throughfall being important as water passes through the foliage resulting in a greater input than that associated with litterfall itself.

Atmospheric deposition was around 80 kg per hectare per year in coastal areas, reducing to 11 kg in continental areas suggesting sea to land transfer of chlorine. Climate was also found to have a significant effect on chlorine deposition resulting in a greater humus concentration. Residence time in soil was found to decrease with increasing chlorine deposition.

A variable situation was noted at different sites that depended on the turnover rate of organic matter. No net accumulation of chlorine occurred in some forests, but accumulation was apparent in others.

The second study (chlorination rate) investigated the difference between soil concentrations associated with three ecosystems (forest, pasture and agriculture). For each ecosystem, around 17 surface soils were sampled which varied in organic matter content. A good correlation was observed between organochlorine and total chlorine in all three ecosystem types. The percentage of organochlorine varied little with ecosystem type (range 83-89%), yet total chlorine and organochlorine concentrations were around twice that in forests compared with agricultural and grassland systems.

The third study (chlorine cycling and modelling) involved the study of a forest site associated with a large data base on biomass dynamics. The study looked at chlorine distribution in soils with maximum levels being observed in humus. Biomass distribution and productivity was used to quantify the cycling of chlorine in terms of flux.

It has been concluded that vegetation is a vector of intense recycling of chlorine, the forest floor serves as a bioreactor for organochlorine formation whilst soil serves as a sink for organochlorine which is associated with organic matter turnover.

Results have been published in an ANDRA report[a].

The information resulting from the above studies has been used to validate a new chlorine model and a good representation of the system is achieved in the models (predicted versus observed values). The model indicates a rapid equilibrium of inorganic chlorine whereas equilibrium of organochlorine is anticipated to take around 2,000 years.

The model has been used to investigate the effect of atmospheric versus underground input to a system. In the case of underground contamination, the final percentage of organic chlorine was lower than for atmospheric input since for the former, trees are the only possible vector for chlorine cycling and its further reaction with humus organic matter. For the atmospheric input around 3% is calculated to accumulate in the system whereas only around 1.5% is calculated to accumulate for a below-ground source.

Further studies on Cl-36 are planned. For example, a PhD has begun on cycling, partitioning, chlorination and dehalogenation and a further PhD has recently been accepted on the detection of Cl-36 and its distribution and transfer between environmental compartments in the Meuse/Haute-Marne area.

Discussion

Leaching of inorganic chlorine is an important loss mechanism from a system and a gradient of Cl:C is observed with depth which may relate to resistance of different pools of organic chlorine to organic degradation. It is considered that the greater abundance of microfungi in forest soils compared with agricultural / grassland soils may lead to increased organic chlorine production.

3.8 UPDATE FROM KAERI

Dr Jeong provided the following comment to the meeting via Graham Smith.

KAERI are currently planning to develop a reference system for the disposal of waste generated from the processing of PWR spent fuel. The reference system is planned to be developed by 2012 and the safety assessment will based on Goldsim.

[a] Thiry, Y., 2010. Contribution à l'étude du cycle biogéochimique du chlore en écosystème forestier : cas d'un peuplement de pin sylvestre (exploitation des données du rapport SCKCEN-R-4922). Rapport Andra ENV.NT.ASTR.10.0068, Agence Nationale pour la gestion des De´chets Radioactifs, France.

4. NEWS FROM OTHER PROJECTS AND PROGRAMMES

An update on other projects and programmes relevant to BIOPROTA, as presented during the workshop, are summarised below.

4.1 EMRAS II WG3: SOLID RADIOACTIVE WASTE

The EMRAS II programme consists of 9 working groups; WG3 focuses on reference models for radioactive waste disposal. The objectives of the group are to further develop reference approaches from BIOCLIM and BIOMASS to consider how environmental change should be taken into account. It is also intended to derive a set of conceptual models for a range of environmental situations. These objectives are intended to be achieved through the use of on-going projects and programmes of the different participants in order to synthesis information and provide solutions. Within the working group there are four subgroups: analogue sites, soil to plant transfer in different climates, dynamic modelling and compliance with protection objectives. The working group is in its third and final year[a].

The analogue sites subgroup has looked at environmental and climate change by considering different areas in Europe as a means to describe future climate situations, i.e. substituting space for time by investigating what is currently happening in different climates. ECOLEGO software has been used to undertake a sensitivity analysis which has identified dose coefficients and root uptake as sensitive parameters. FEP lists are currently being generated for different reference biospheres and it is planned that the sensitivity analysis will be improved and refined prior to being compared against an uncertainty analysis.

Within the soil to plant system subgroup, four types of model are being investigated (CIEMAT, SCK.CEN, SSM and Nottingham University models).

The dynamic modelling subgroup aims are focused on using work from the SKB and the Posiva safety cases (including a perspective wider than plain biosphere assessment, e.g. towards handling the climate issues) as input to identify how processes can be handled in models. The subgroup is linked to the analogue subgroup in describing future sites.

Subgroup 4 on demonstrating compliance with protection objectives is looking at the issues from a regulatory perspective. It is acknowledged that is some countries the regulations are too prescribed whereas in others there is a lack of guidance. As such, the objective is to consider whether the work of the other subgroups help in meeting international guidance and requirements. Where issues are identified, it is hoped that this information can be fed back to the IAEA which may lead to modifications in order to improve coherence.

4.2 EMRAS II WG2: NORM AND LEGACY SITES

Working group 2 is focussed on developing reference approaches to modelling in support of management and remediation at NORM and legacy sites. The majority of participants are interested in NORM from a uranium mining and milling perspective, but legacy sites associated with weapons testing etc are also of interest.

[a] The final EMRAS II plenary meeting is planned to take place in March 2012. IAEA is currently canvassing for ideas for an EMRAS III programme.

Sites affected by uranium mining activities (tailing piles and ponds) can vary in radioactivity content; tailing piles are in general of lower activity than sediments in ponds. The quantities of waste associated with such sites on a mass unit base are generally much larger, but with a lower radioactivity content, than arise from the back end of the nuclear fuel cycle, but the dose assessment issues are very similar.

Currently there is no international methodology by which legacy issues can be addressed, hence one objective is to produce a general assessment methodology progess (GAMP) that can be used by assessors in order to develop scientifically-based assessments for submission to decision-makers.

A draft procedure has been produced and this is currently being evaluated as to whether it meets the objective.

There is a significant overlap in the radionuclides of interest between WG2 and WG3 such that there has been scope for sharing experience in relation to long-term modelling and monitoring.

4.3 STAR: IDENTIFICATION OF RADIOECOLOGY NEEDS

Deborah Oughton presented.

STAR is an EC funded project to develop a network of excellence in radioecology. There are various work programmes and UMB are leading work package 6 on education and training. It is recognised that it is important to work with industry to identify the needs of employees and to then produce students with the required skills through the development of relevant courses that will meet future societal needs. A workshop was recently held in Helsinki as part of WP6 which looked at demands, i.e. focussed on the needs of employers. A second workshop is planned that will look at how to supply these required skills and how best to design courses. As such a greater academic presence is anticipated at this latter workshop.

Twenty people attended the Helsinki workshop. Three sessions were held; setting the scene, what skills are required, and implementing education and training in the workforce.

The need for radioecologists is recognised in relation to new nuclear build – there will be a requirement to demonstrate the level of impact on people and the environment. It is also recognised that there is inconsistency in the requirement of regulators for the nuclear and chemical industry with chemical industry regulators largely being interested in numbers that aid in the understanding of risk whereas nuclear industry regulators often focus more on understanding those numbers (source and application). Within the field of radioactive waste management it is acknowledged that there is a real need for radioecology, particularly in relation to deriving information for key radionuclides of importance. Other drivers for radioecology skills relate to decommissioning activities and NORM and legacy sites, but also the day to day operations of regulators (e.g. in regulating hospital discharges). National security issues are also driving forward urban radioecology.

There is some inconsistency in the definition of radioecology and a common understanding is required to fully understand the drivers. It was agreed during the workshop that this included both the natural and human environment.

It was noted that education networks are available and could prove valuable but there is a need for student internship opportunities to allow students to gain industrial experience. A PhD research network is planned with the aim of enabling students to join a virtual network that will provide courses that anyone within the network can join.

5. FORWARD BIOPROTA PROGRAMME

A number of possible topics were identified for the forward work programme that are presented briefly in this section for consideration. Organisations interested in particular programmes are requested to contact the technical secretariat such that actions can be coordinated.

- **International workshop on the behaviour of redox sensitive radionuclides at the geosphere-biosphere interface.** A workshop is being planned for 6-8 September 2011 in Belgium. ANDRA is the lead organisation with support from the BIOPROTA technical secretariat. Funding has currently been pledged from ANDRA and NUMO. However, additional financial support is requested to support the attendance of invited experts and organisational matters. Organisations interested in supporting the workshop should contact gmsabingdon@btinternet.com. Further information on the workshop is available from ks@eden-ne.co.uk.

- **Carbon-14 modelling**. Participants of the current project have identified the need for further critical inter-comparison of C-14 models to investigate the reasons for differences in model results. Further investigation to increase the understanding of (and data in support of) dispersion and diffusion of C-14 in the plant canopy may also be warranted.

- **U-238 series radionuclides**. Extension of the current study to radionuclides lower in the decay chain (i.e. Ra-226 – Pb-210 – Po-210). Further consideration of disequilibrium is required within the current project by drawing out information from the results prior to any extension.

- **Radon emanation and dose assessments**. Monitoring data from NORM contaminated sites could be used as a means of validating models. It was noted that IRSN has a particular interest in modelling radon emanation to the biosphere, but also to buildings that could be constructed on NORM contaminated sites and on-going research on this subject is under discussion. It was also noted that LLWR have historically had an interest in this subject.

- **Non-human biota continuation**. Depending upon the outcome from the Glasgow workshop on compliance demonstration, there may be merit in undertaking a trial application of the developed methodology and/or to analyse available effects data to derive screening criteria in line with the developing assessment concept.

- **Chlorine-36**. There is continued interest in the application of models to data from field and/or experimental work as a means of validating Cl-36 models.

- **Human Intrusion**. Following the completion of the current project, there may be merit in considering implications of human intrusion combined with natural processes (e.g. land uplift combined with disposal depth considerations and intrusion scenarios). This subject has previously been identified as of interest to NUMO.

- **Non-rad impacts of radionuclides and leaching of non-radioactive materials associated with radioactive waste disposal**. NDA RWMD has previously investigated the potential chemotoxic impacts of radionuclides and non-radioactive materials (e.g. beryllium and uranium). Further consideration of the non-radioactive impacts from materials transported to the biosphere from the near field may be warranted.

- **Validation of biosphere models against field data**. This subject was highlighted as of particular interest to NWMO and KAERI, and the idea was raised that we could revisit the idea of whether historical data on the dispersion of radionuclides following discharge to the environment could be exploited in this context.

In addition, the list of actions arising from the 2010 workshop was briefly discussed and, where appropriate new actions identified. These are outlined in the following table.

Topic	Previous action/comment	New action / comment
Characterisation programs and information / experience sharing	Maintain the link with EMRAS II WG3	Continue with WG3 And WG2 NORM
Stable element versus trace radionuclide data, which is better, when, why?	Can the two approaches be complementary?	This approach is being developed by research at NRS, Japan, among others.
Information for cold climates	Nagra, NRPA ANDRA and other reports of potential value could be made available. Link to EMRAS WG3.	2009 AMAP Radiaoctivity report includes relevant information on arctic radioecology and dose assessment, available at http://amap.no/ under the publications tab.
Se volatilisation and redox behaviour in soils	To be considered in Phase II Se-79 project	Final report for Phase II, if sponsors agree, due at end September
Data interpretation and application of the new IAEA TRS 472 data compilation	For information, need to access underlying references	
Use CR instead of TF for transfer to animals	Use of allometric models. Ideas are invited for way of refining current approaches	
Detection limit for plant CR, e.g. because of soil adhesion	Ensure do not double count, although implications probably low. IAEA report on deposits & contributing elements by Wyttenbach may be relevant.	
IAEA is developing a new guide on the Safety Case and Safety Assessment for Radioactive Waste Disposal		Does SSR-5, the new 2011 IAEA waste requirements document, change what we need to consider in repository assessment
Changes in our understanding of that sensitivity, in terms of radiation in general and in terms of the effects of individual radionuclides.	See next topic	

Topic	Previous action/comment	New action / comment
Closer consideration of uncertainties in dose coefficients	Mike Thorne interested to write a note identifying issues for key radionuclides, such as I-129. ICRP are currently looking to update dose coefficients	Mike Thorne & Laura Limer to take forward
Analogue approach to environmental change	EMRAS II WG3 is considering this approach	
Assessment of the future dynamic evolution of a site	Complementary approach to that in topic above, also being considered in EMRAS II WG3.	
Comparing Biosphere Dose Conversion Factors (BDCFs) for key radionuclides	Simplistic results comparison may be problematic since methods of computation are very different. However, this approach may lead to early identification of the main differences in approach, which may need to be justified, or mitigated. Graham Smith interested to write a note identifying scope and possible value. … Other contributions are invited.	Jongtae Jeong (KAERI) has suggested as a topic: comparison of the biosphere assessments.
Tools for Knowledge Quality Assessment for the biosphere are part of the overall performance assessment	Posiva methodology available.	JAEA approach may be of interest and developed further.
Applying the CIEMAT Se-79 model to U series, Tc-99 and other redox sensitive nuclides	Being done in U-238 series project	Further consideration of Tc-99 may be appropriate.
Reactive chemistry approach to effective Kd estimation in heterogeneous media. how to handle redox sensitive elements	AMPHOS work for SKB in progress	Results due to be presented in Louvain workshop.
Use of information on site investigation, e.g. Bayesian statistical tools to combine data distributions.	A BIOPROTA workshop on Bayesian statistics was suggested. Ideas expanding on this suggestion are invited.	
Stylised approach to human intruder dose assessment	Project in progress, Draft final report, July august	Scenarios combining natural and Human Action processes.

Topic	Previous action/comment	New action / comment
Transitions in biosphere conditions and potentially related acute releases across the geosphere-biosphere interface. How to identify? How to assess?	Assessed acute affects are sometimes generated as modelling artefacts, but may also be expected to arise in the real world as a result of human actions and natural change, or in combinations of both. Is modelling of change through a step transition process adequate? Are there contexts where we need to be more realistic?	Take account of EMRAS II WG3 output.
Specialised database development	Participants are asked to consider the options suggested by Thomas Hjerpe.	
Non Human Biota dose assessment for waste repositories	Current project on demonstrating compliance in progress.	Trial application of compliance methodology; analysis of effects data to derive CBLEL.

6. FORUM ADMINISTRATIVE ISSUES

6.1 2012 FORUM MEETING

The 2012 BIOPROTA workshop will represent the 10 year anniversary of the forum and, as such, an extended workshop has been suggested. ANDRA has agreed to host the meeting at Nancy in the north of France, which would allow for a visit to their monitoring site during the workshop.

A provisional agenda could be as follows:

- Day 1 – presentation of agency programmes
- Day 2 – scientific talks from invited speakers
- Day 3 – ANDRA monitoring site visit
- Day 4 – working group activities.

Ideas for the focus for day 2 include common monitoring interests and exchange of information on monitoring approaches, how to categorise the functioning of systems and categorising risk in terms of ecosystem function, what knowledge is required in relation to specific radionuclides and/or what knowledge is required in relation to specific sites (identifying why there are differences in how sites are described)[a].

Agreement on this suggestion is required and alternative suggestions for location and/or focus are invited.

6.2 BIOPROTA CHAIR FOR 2011/12

Simon Norris (NDA RWMD) volunteered to chair the forum for the coming year and, subsequent to the workshop agreement was made by the sponsoring organisations.

BIOPROTA participants took the opportunity to thank Sven Keesman (NAGRA) for his hard work during 2010/11 as the forum chair.

6.3 INPUT TO PARALLEL WORK PROGRAMMES

The IAEA are currently inviting interested parties to suggest ideas for working groups for the EMRAS III programme, due to start in 2012/13. Forum members are requested to consider ideas that could be put forward that would be complementary to BIOPROTA activities.

[a] It was noted that the NDA RWMD have recently undertaken a review of site characterisation work based on experience in Finland, Sweden, Canada and the UK). The report is currently under review and is due to be published later in 2011.

6.4 APPENDIX A. LIST OF PARTICIPANTS

Participant	Affiliation
Yves Thiry	ANDRA, France
Danyl Perez-Sanchez	CIEMAT, Spain
Steve Sheppard	EcoMatters, Canada
Karen Smith	Eden Nuclear & Environment, UK (BIOPROTA Technical Secretariat)
Graham Smith	GMS Abingdon, UK (BIOPROTA Technical Secretariat)
Marie-Odile Gallerand	IRSN, France
Takashi Nakamura	Japan NUS Co Ltd, Japan
Laura Limer	Limer Scientific Consulting, China
Sven Keesmann	NAGRA, Switzerland
Chantal Medri	NWMO, Canada
Paul Gierszewski	NWMO, Canada
Neale Hunt	NWMO, Canada
Kathryn Higley	OSU, USA
Ari Ikonen	Posiva, Finland
Thomas Hjerpe	Saanio & Riekkola, Finland
Sten Berglund	SKB, Sweden
Tobias Lindborg	SKB, Sweden
Ulrik Kautsky	SKB, Sweden
Shulan Xu	SSM, Sweden
Deborah Oughton	UMB, Norway