BIOPROTA

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

Update and Review of the IAEA BIOMASS Methodology

Summary of the Sixth Workshop Held in Parallel with the Third Technical Meeting of MODARIA II Working Group 6

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Version 2.0, 20 December 2018

PREFACE

BIOPROTA is an international collaborative forum that 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 assessments required in many countries. The collaborative work 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 placed on key data required for the assessment of long-lived contaminant migration and accumulation in the biosphere, and the associated 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 collaborative effort can be applied to finding solutions.

This report provides a summary of the presentations and discussions during a technical workshop of the BIOPROTA project to review and enhance the IAEA BIOMASS methodology. The workshop was held jointly with the third Technical Meeting of Working Group 6 (WG6) of the International Atomic Energy Agency (IAEA) second phase programme concerning Modelling and Data for Radiological Impact Assessment (MODARIA II). The meeting was held at the IAEA in Vienna, Austria, from 22-25 October 2018. The objectives of WG6 are consistent with those of the BIOPROTA project, and the two projects met together to facilitate the sharing of knowledge and experience and to help coordinate parallel work, avoiding unnecessary duplication of effort.

Version History

Version 1.0: Draft workshop report prepared by Karen Smith (RadEcol Consulting Ltd) based on participant contributions and reviewed by Russell Walke (Quintessa Ltd) prior to distribution on 20 November 2018 to workshop participants and BIOPROTA project sponsors for comment.

Version 2.0: Final workshop report prepared by Karen Smith (RadEcol Consulting Ltd), taking account of comments received from participants on the version 1.0 report. Distributed to workshop participants and BIOPROTA project sponsors on 20 December 2018.

CONTENTS

1. INTRODUCTION

The International Atomic Energy Agency (IAEA) report on reference biospheres for solid radioactive waste disposal was published in 2003[a], following extensive international collaborative work within the BIOMASS programme running from 1996 until 2001. The report sets out a structured approach for the assessment of impacts of radionuclide releases to the biosphere from radioactive waste disposal facilities. The BIOMASS methodology has been used to support a wide range of radioactive waste disposal assessments. Understanding gained through these assessments and other inputs has given rise to new knowledge and developments. For example, there have been significant developments in relation to how climate and landscape change are addressed in long-term assessments and in approaches that allow potential radiation effects on the environment to be explicitly evaluated. There have also been technical developments in models for contaminant migration and accumulation in different parts of the environment, and improved models for assessing doses from the resultant concentrations in relevant environmental media, including radionuclide-specific models for C-14, Cl-36 and Se-79, as reported at www.bioprota.org. There have also been significant updates since 2003 in international recommendations on standards and methods for assessment of post-disposal radiological impacts, from the IAEA, the International Commission on Radiological Protection (ICRP) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD).

Noting the above, it was considered timely[b] for the BIOMASS methodology to be internationally reviewed and enhanced to take account of this new knowledge and experience. As such, a BIOPROTA project was initiated in 2016. The project is supported by a Technical Support Team (TST) comprising Quintessa, GMS Abingdon, RadEcol Consulting and Mike Thorne and Associates. Working Group 6 (WG6) of the IAEA second phase programme concerning Modelling and Data for Radiological Impact Assessment (MODARIA II) also commenced in 2016 and had consistent objectives with regards to enhancing the BIOMASS methodology. The two programmes are being co-ordinated to help facilitate the sharing of knowledge and experience and avoid unnecessary duplication of effort.

Since the start of the BIOPROTA project in 2016, five workshops have been held prior to October 2018:

- A BIOPROTA workshop, hosted by FANC in Brussels, Belgium in April 2016 provided a first opportunity to present and discuss experience and suggestions for methodological improvements[c].

[a] International Atomic Energy Agency (2003). "Reference Biospheres" for Solid Radioactive Waste Disposal: Report of BIOMASS Theme 1 of the BIOsphere Modelling and ASSessment (BIOMASS) Programme, IAEA-BIOMASS-6, IAEA, Vienna.

[b] BIOPROTA (2015). Continuing Issues in Biosphere Assessments for Radioactive Waste Management. Report of a workshop held 28 - 29 May 2015, in Madrid, hosted by CIEMAT.

[c] BIOPROTA (2016). Update and Review of the IAEA BIOMASS-6 Reference Biospheres Methodology. Report of the first programme workshop held 20-22 April 2016, hosted in Brussels by FANC, Version 2.0.

- A second BIOPROTA workshop was then held in combination with the first Technical Meeting (TM) of Working Group 6 (WG6) of the IAEA MODARIA II programme in October-November 2016 at which enhancement activities were assigned to the BIOPROTA project TST[d].
- A third BIOPROTA workshop was then held in May 2017 with the first Interim Meeting (IM) of WG6, hosted by ENSI in Brugg, Switzerland at which progress was reported on assigned activities[e].
- The BIOPROTA project then delivered a draft interim report as input to a fourth workshop, which was held in combination with the second WG6 TM in Vienna October-November 2017[f]; the interim report was finalised after the meeting and published under SKB covers[g].
- A fifth BIOPROTA workshop was then held in May 2018 with the second IM of WG6, hosted by Posiva in Kerava, Finland, that further discussed and built upon the interim report with tasks being set as input to the further enhancement of the BIOMASS methodology.

This report provides a summary of the presentations and discussions during the sixth BIOPROTA project workshop, held in conjunction with the third WG6 TM that was held at the IAEA, Vienna, Austria in October 2018.

1.1 AIMS AND OBJECTIVES

The overall aim of the BIOPROTA and WG6 projects is to retain the same basic methodological steps set out in the original BIOMASS methodology, i.e. not to change the overall approach, but to bring it up to date based on new scientific information, experience from assessments and model developments, revised international recommendations and regulatory and other practice and experience.

The specific objectives of the joint project workshop and third WG6 TM were:

- to present progress on agreed activities following the previous meeting;
- to review and further improve material published in the interim report;
- to hear from organisations about their on-going interests in this area; and

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[d] BIOPROTA (2017). Update and Review of the IAEA BIOMASS Methodology. Report of the second workshop held in parallel with the first meeting of MODARIA II Working Group 6 held 31 October to 4 November 2016, hosted in Vienna by IAEA, Version 2.0.

[e] BIOPROTA (2017). Update and review of the IAEA BIOMASS Methodology. Summary of the third workshop held in parallel with the first interim meeting of MODARIA II Working Group 6 held 10-12 May 2017, hosted in Brugg by ENSI, Version 2.0.

[f] BIOPROTA (2018). Update and Review of the IAEA BIOMASS Methodology. Summary of the fourth workshop held in parallel with the second Technical Meeting of MODARIA II Working Group 6 held 30 October to 3 November 2017, hosted in Vienna by IAEA, Version 2.0.

[g] Although published as a BIOPROTA report under SKB covers, the interim report documents intermediate progress towards developing an update to the BIOMASS methodology, drawing on collaboration between the BIOPROTA and WG6 projects. It is intended that the further development of the interim report through collaboration between both projects throughout the remainder of 2018 and into 2019 will result in a final draft report for delivery prior to the next joint meeting in May 2019. The final report is due to be completed by the end of 2019.

- to agree on the next steps for the BIOMASS methodology enhancement.

1.2 WORKSHOP PARTICIPATION

The workshop was held at the IAEA, Vienna, Austria, from 21-25 October 2018. The meeting was attended by 27 participants from 11 countries. Participants are listed in Appendix A.

1.3 REPORT STRUCTURE

Section 2 of this report summarises the presentations and discussions during the meeting. Section 3 then summarises the agreed actions and responsibilities.

2. OVERVIEW OF WORKSHOP PRESENTATIONS AND DISCUSSIONS

Summaries of the presentations from participants are provided below, along with key discussion points. Where presentations were made by members of the TST based on the interim report, only brief summaries of the main points from the presentations are given, with the focus being on reporting of associated discussions, and identification of actions for the next phase of the project.

2.1 OPENING PLENARY

Tobias Lindborg (SKB and WG6 leader) opened with a plenary presentation summarising the activities of WG6 (and the associated BIOPROTA project), including plans for the workshop.

There have been a number of methodological guidance documents developed as a result of IAEA collaborative programmes, including:

- BIOMASS-6. Reference Biospheres for Solid Radioactive Waste Disposal, Report of BIOMASS Theme 1 of the BIOsphere Modelling and ASSessment Programme (2003).
- TECDOC 1799. Environmental Change in Post-Closure Safety Assessment of Solid Radioactive Waste Repositories. Report of WG3 EMRAS II (2016).
- Common Framework for Addressing Climate Change and Landscape Development in Post-Closure Radiological Assessment of Solid Waste Disposal. Report of WG6 of MODARIA, submitted to the IAEA in October 2016.

These, together with other experience and developments, are being used to inform on the enhancement of the BIOMASS methodology. The areas requiring enhancement, identified to date through the activities of WG6 and the BIOPROTA project are highlighted in Figure 1.

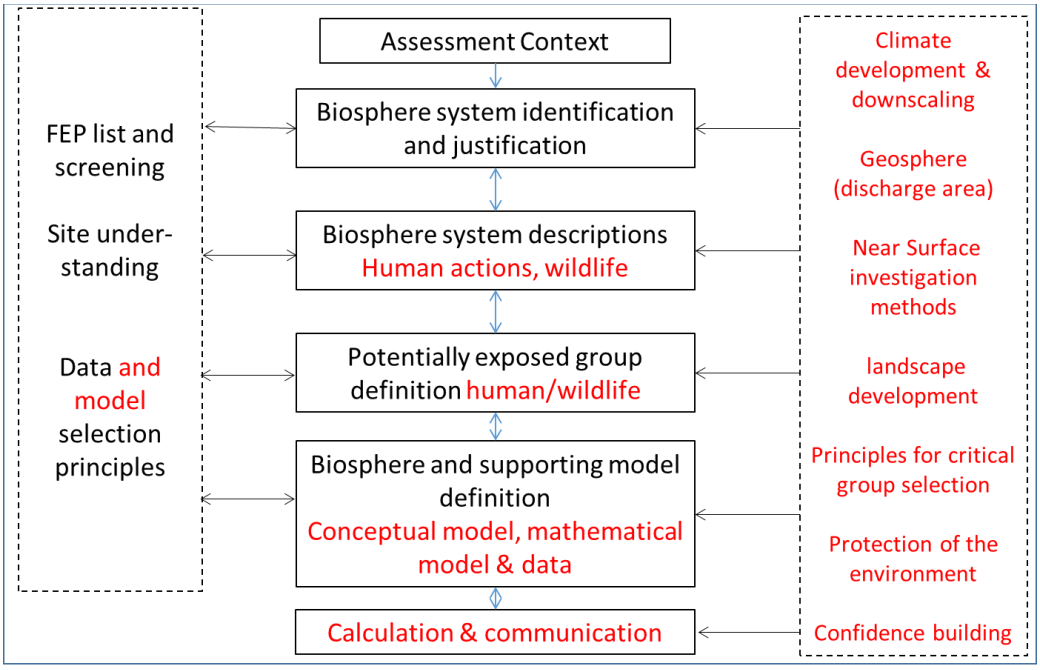

Figure 1. BIOMASS methodology enhancement areas (shown in red).

The approach taken to enhance the methodology has been to define writers and editors for particular sections of the methodology, taking account of input from participants (direct technical input and presentations/discussions during meetings) and review of scientific findings and results. Several meetings (annual and interim WG6 meetings held together with workshops of the parallel BIOPROTA project on enhancement of the BIOMASS methodology) have taken place and an analogue environment field study was organised in Greenland in June 2018.

The scope of activities includes both deep geological disposal and near-surface disposal of all types of solid radioactive wastes across a wide range of geographical environments. The overall objectives are to evaluate, update, clarify and, as appropriate, extend the methodology, delivering a report that:

- describes the biosphere assessment strategy and how it links to the overall safety assessment so as to support transparent evaluation against protection objectives;
- builds on the biosphere concept and describes the lessons learned since 2001, including from the BIOPROTA program;
- describes supporting information/system description models needed for dose modelling;
- extends consideration to a wider range of geographical environments;
- links landscape environmental change (MODARIA I) to dose modelling;
- assesses latest science that supports all the above; and
- describes how site understanding functions as a basis for model development.

An interim report has been published (as SKB Report R-18-02) that aims to provide a framework for further discussions, provoke suggestions, and provide a basis for the latest work in this area. The report also includes placeholders for work that remains to be done.

The interim report has already been built upon. An interim meeting was held in Finland in May 2018 where many remaining development areas were discussed, and further actions placed to ensure progress on specific tasks. The objectives of the current technical meeting of WG6 were therefore to present and discuss progress in each of these areas, provide an opportunity for presentations on international experience and scientific/technical developments and to update the work plan with further task allocation.

2.2 PAGODA: ASSESSMENT OF POTENTIAL RADIOLOGICAL IMPACTS IN POST-CLOSURE PERIOD OF DISPOSAL FACILITIES: LINKS WITH MODARIA II

Joanne Brown (ERC) and Alena Zayazanova (IAEA) presented an overview of a joint EU and IAEA project, PAGODA that is aimed at responsible and safe management of radioactive waste and spent nuclear fuel through the assessment of potential radiological impacts in the post-closure period for disposal facilities. The focus is on providing guidance to those countries without current expertise in developing safety cases for near-surface disposal facilities and, potentially, geological disposal facilities for radioactive waste and is intended for use during planning or scoping studies for radioactive waste disposal facilities. The methodology is therefore required to be simple yet robust and site-generic, building on information within SSG-23 and drawing from current extensive experience and knowledge in this area and, particularly, the output from various IAEA projects including BIOMASS, EMRAS and MODARIA. The project launched in 2017 and will run for four years.

Biosphere assessment forms part of the guidance that will be included within PAGODA. The approach to the biosphere is being based around the BIOMASS methodology and will include guidance on approach, models and data and cover topics such as possible entries of radionuclides to the biosphere, climate and future climate change, landscape and its development, including possible land use, and radioecological modelling to estimate doses to representative persons and non-human biota. One of the challenges faced in developing the approach for radiological impacts during the post-closure phase is providing a suitable balance to the guidance for a simple approach that can be applied in a site-generic context whilst recognising where site-specific information is important. Being clear on the questions being asked is paramount since decisions around the application of the method must be informed by the purpose and objective of the assessment. The guidance will be supported by examples illustrating the application of aspects of the methodology. Work to date has focussed on reviewing relevant programmes and experience and drafting a high-level outline approach.

For climate, a simple non-sequential approach is envisaged with a number of climate analogues being used to scope the possible changes in climate change based on the present-day biosphere and its historical evolution. Work undertaken within the MODARIA programme will be used to inform the development of this guidance.

In terms of human activities and exposure groups, assessments are focussed a long time into the future and a robust yet simple approach to selecting habits etc. will be required. The intention is, therefore, to focus on current or foreseeable habits for relevant timescales and scenarios such as subsistence farming and use of contaminated surface waters for fishing, with associated exposure pathways.

Features, events and processes (FEPs) and interaction matrices (IMs) will also be covered and one aspect in developing the guidance will be to consider how straightforward FEP lists can be for people starting out in the assessment process. The intention is to include discussion around how FEP lists can be used at different stages of the process. Again, the intention is to draw from information presented within the enhanced BIOMASS methodology, including any examples around the use of FEP lists in screening important processes over different timeframes.

Guidance on a screening approach for non-human biota dose assessment will also be included. This will be based around the ICRP Reference Animals and Plants (RAPs) approach, but also take account of guidance being developed for the enhanced BIOMASS methodology relating to appropriate averaging approaches for contaminant concentrations.

Throughout the development of the PAGODA guidance, the intention is to signpost to sources of generic data that could be useful, but also to provide example applications that could help guide assessors in the application of the methodology. The information included within the enhanced BIOMASS methodology will be an important input to the PAGODA project, particularly information relating to generic data sources and guidance around what is likely to matter for assessments that can help guide site characterisation as safety cases develop.

Some key questions raised for discussion were:

- whether or not generic biospheres can be used to generate an envelope of potential doses/endpoints?
- whether an agricultural well scenario could be considered as a worst-case scenario for a generic site?

- whether or not generic default 'models' and / or parameter values could be provided as a starting point for people new to assessments?
- could equilibrium biosphere dose conversion factors (BCDFs) be calculated and provided for some reference biospheres and climate scenarios?

The intention is for a TECDOC to be delivered by mid-2020, alongside training materials.

Discussion

There is considerable overlap between the MODARIA II BIOMASS enhancement WG and the PAGODA project. The BIOMASS enhancement is aimed at all audiences, irrespective of the level or experience or whether an assessment is generic or site-specific in context. PAGODA, however, is more focussed toward new users and site-generic contexts.

In response to the questions raised, it was explained that no 'reference biosphere' examples would be included in the enhanced BIOMASS methodology. Rather, real examples will be included, drawing from assessments that have been undertaken to date, for site-generic through to site-specific contexts. Each example will be tied to an assessment context so that, if a particular example fits with another assessment context then it could be justifiably used. However, where this is not the case, assessors would need to consider how to adapt the example to the specific situation being addressed.

In discussing examples for inclusion in the guidance, it was suggested that effort should be given to providing illustrations that not only demonstrate the approach, but that also raise awareness of available resources, such as the climate work undertaken within WG6 of MODARIA I and associated climate model resources that provide information that can be extracted for different contexts. It will be important to recognise that, for climate in particular, the biosphere cannot be considered in isolation; changes in climate have the potential to impact the entire disposal system. Furthermore, whilst the intended non-sequential approach to climate may be appropriate and justifiable for generic assessments for geological disposal facilities, it may be difficult to justify such an approach for near-surface facilities due to the more rapid dynamics of the system.

It was suggested that a particular point that should be captured in the guidance being developed within the PAGODA project is the need for special models for some radionuclides (e.g. C-14 and redox-sensitive radionuclides). There are various BIOPROTA reports available that address modelling needs for such radionuclides. A further point to capture will be that multiple lines of argument are needed to make a safety case and that dose assessment is just one aspect.

Site-generic assessments are very useful in early stages of a programme, including supporting site selection. However, as soon as a site has been selected, there should be a move away from a generic assessment approach to a more site-specific approach. Once a site has been well characterised and site understanding developed, it may be possible to justifiably apply a simpler assessment approach, but this must be informed by the site. The experience of those that have been through the process (from site selection through to site characterisation and site-specific assessments) will be valuable in helping to guide others in what to look for, lessons learned and the need for continued iteration. Appropriate examples can be referred to within the updated BIOMASS methodology. For example, SKB are currently embarking on a site-generic assessment for a disposal facility for intermediate-level wastes (SFL), but this is drawing on a wealth of knowledge gained during previous site-specific assessments and associated site characterisation programmes. Whilst the assessment is site-generic, illustrative site characterisation data are being applied with the intention of identifying what information can be site

generic and where site-specific data are needed. Further information on this study is summarised in Section 2.11.

The offer was made for representatives from the BIOMASS enhancement project to attend future PAGODA meetings or to review material produced to assist in the development of guidance within the project.

2.3 CURRENT STATUS OF THE BIOMASS ENHANCEMENT PROJECT

Russell Walke (BIOPROTA TST) gave an overview of the current status of the BIOMASS enhancement project to ensure all workshop participants were familiar with work undertaken to date and aspects under active development. It is important for all project participants (both in terms of BIOPROTA and WG6) to be happy with the material contained within the report as it develops. All participants are invited to review material produced to date, to provide feedback and suggestions for improvements and examples to illustrate specific aspects of the methodology. Technical contributions are also actively encouraged.

It is intended that examples will be collated within an appendix rather than being included within the main body of the report to avoid any misconception that specific assessment programmes are in some way recommended or endorsed. For each step of the method, thought is needed as to appropriate illustrative examples. The examples should be balanced between generic and site-specific contexts and cover a range of different climate conditions.

Iteration in assessments continues to be highlighted in discussions around the methodology enhancement, but the need for iteration can be difficult to illustrate in flow diagrams. It may however be possible to illustrate the need for iteration and how to handle this in practice through the examples provided. One useful example in this regard could be the SKB SFL safety evaluation, which is site-generic, but builds on considerable experience in undertaking site-specific assessments (see Section 2.11).

A glossary of terms is to be added to the enhanced methodology. However, the IAEA have recently made their Safety Glossary available online[h] and this should be adhered to as much as possible, with only terms not included in this online glossary being included within the report.

Figures depicting the overall BIOMASS methodology (Figure 1-2 in SKB R-18-02) and illustrating the position of biosphere assessment within an overall safety case (Figure 1-1 in SKB R-18-02) are important focus areas for the methodology enhancement, with alternative versions being discussed during previous workshops. Updated versions have been produced in the light of discussions during the 5th project workshop and were presented for comment and discussion. A revised figure illustrating biosphere

[h] https://kos.iaea.org/iaea-safety-glossary/195.html

assessment within the overall safety case is presented in

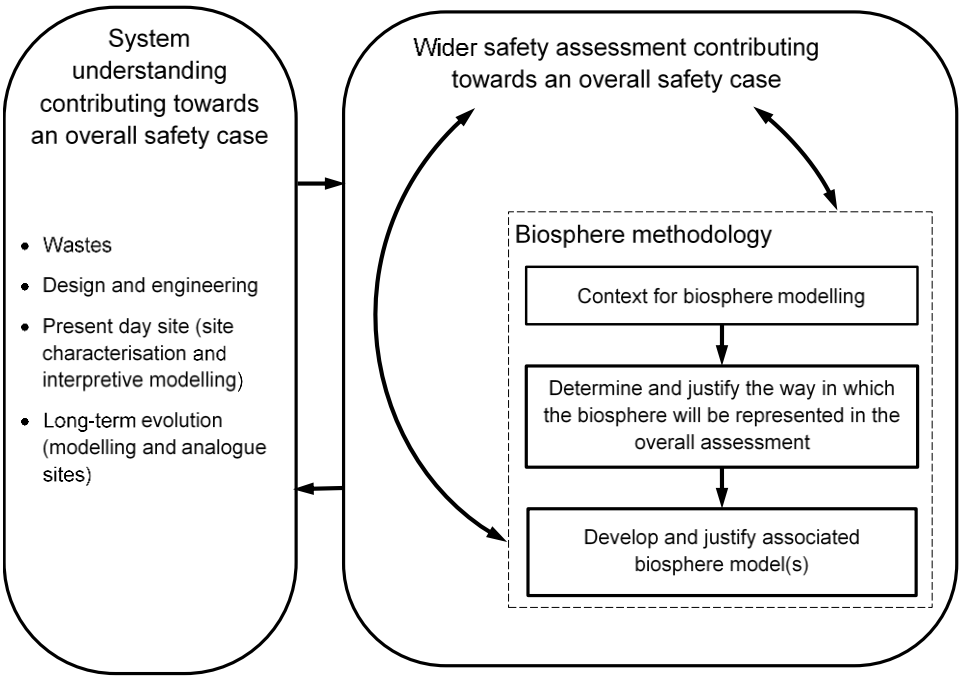

Figure 2. A revised version of the circular methodological flow diagram presented by Ulrik Kautsky (SKB) during the 5th project workshop is presented in Figure 3.

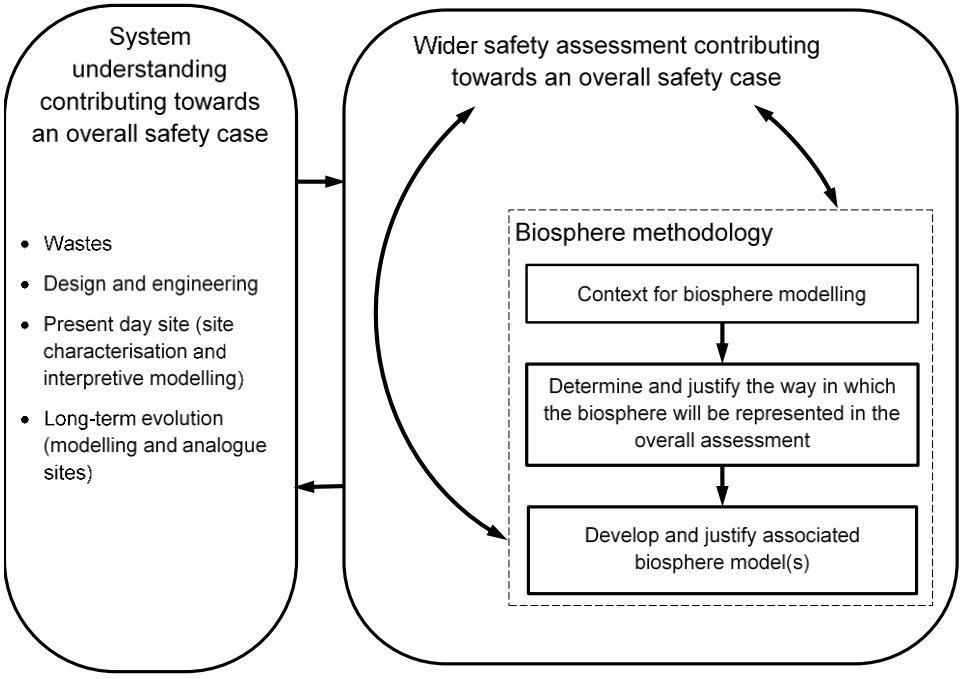

Figure 2. Alternative version of Figure 1-1 in SKB R-18-02 to illustrate the biosphere methodology in the wider safety assessment context, presented for discussion.

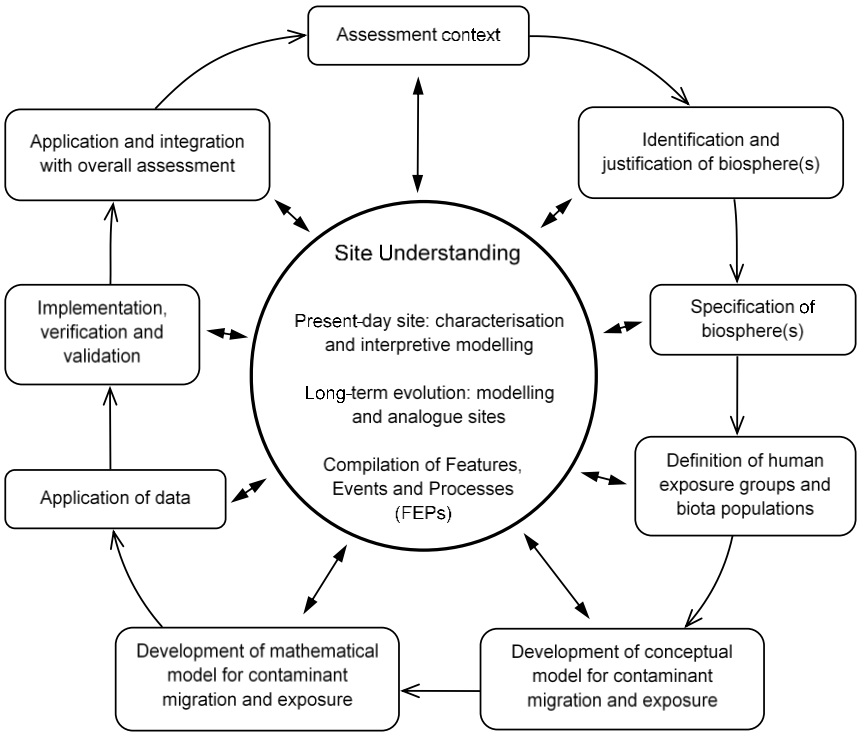

Figure 3. Revised circular workflow diagram for the BIOMASS methodology.

Suggestions for revisions to Figure 2 were as follows:

- A specific link should be added to SSG-23.
- 'Wider' should be removed from 'wider safety case'.
- Iteration/feedback should be made clearer between system understanding and safety assessment.
- Where long-term evolution is mentioned, 'climate and landscape evolution' should be added.
- The previous version of the figure gave mention to the geosphere, which is lost from this version. Reference to the geosphere should be incorporated once more, but this could be by way of images rather than words.
- In the lower right box there is mention of models, but not results, yet it is the results that should feed back to the safety case.

Figure 3 aims to depict site understanding as being at the heart of the work flow and is intended to be used alongside the original stepwise version of the figure (Figure 1-2 in SKB R-18-02). Nonetheless there was some concern that this version is difficult to follow since it does not give a clear start or finish point. Other suggestions / comments raised during discussion were as follows:

- Reference to FEPs could be removed.
- A link to regulatory review should be added after 'application and integration with overall assessment'.

- Thought should be given to the addition of start and exit arrows.
- The original version presented by Ulrik Kautsky had understanding from the site as the centre focus rather than site understanding and this may be a preferred term by some.

Overall, development of site understanding was considered a better term to use rather than site characterisation. The characterisation of a site is a method by which site understanding can be improved and it is this understanding that is required to support model development. The site descriptive model then supports assessment models. Site understanding is important at all stages of assessment, including generic stages. Additional arrows could be added to the linear methodology flow diagram to show feedback from assessment stages back to site characterisation/site understanding.

2.4 MODELLING LONG-TERM CLIMATE CHANGE

Mike Thorne (BIOPROTA TST) presented an update of work undertaken by Bristol University on behalf of SKB and Posiva. The presentation followed from that given during the 5th project workshop by Natalie Lord (Bristol University). The project has aimed to address the following key questions relating to climate change at Olkiluoto and Forsmark:

- When will the next glaciation occur?
- How might future anthropogenic warming affect climate and the timing of the next glacial inception?
- Which climates are possible in the future and how do periglacial, glacial and interglacial climates affect repositories (geosphere and biosphere)?

A climate emulator has been developed that uses three forcings: orbital elements; atmospheric CO_2 concentration; and global ice volume (for which global sea-level is used as a proxy). Three atmospheric CO_2 emissions scenarios have been used, along with a control scenario that assumed CO_2 emissions have remained at pre-industrial levels. Together with orbital forcing, the CO_2 concentrations are used to force the global sea level model.

Two separate emulators have been used; one for glacial conditions and one for interglacial conditions. The emulators have been validated against various time series and spatially distributed palaeo data sets, including Antarctic ice-core and deep ocean sediment-core data. It should be noted that, whilst changes in the ice sheets in response to atmospheric CO_2 can be represented by the emulator, the impact of these changes on the carbon dioxide dynamics of the Earth and climate system cannot be captured.

A physical-statistical downscaling technique has been applied to derive regional data from the global climate emulations. This requires the assumption that current relationships between predictors and predictands will be the same in the future for both global warming and cold glacial conditions.

Whilst the approach has some limitations, it is a considerable advance on the approach used in MODARIA I and provides an appropriate and self-consistent tool for making projections both of the implications of future greenhouse-gas induced warming and of the transition back from such conditions to glacial-interglacial cycling. Whilst work to date has focussed on the northern hemisphere, the emulator gives global climate for any area of interest (site or generic).

Discussion

The emulator has the ability to output in timesteps down to 15 minutes, but the output data sets are vast and it is not feasible to store all climate variables in such short timesteps. Key parameters are therefore stored for daily intervals. New model runs of the underpinning AOGCM will be required if shorter timesteps are needed.

As a result of the work with the emulator to date there are examples of application to the northern hemisphere. An example for an alternative climate region would be useful to illustrate its application in another context. In addition, examples of the application to shorter timescales (e.g. for near-surface disposal facilities) would be useful.

2.5 SITE SPECIFIC MODELLING OF COLD REGION HYDROLOGY

Emma Johansson (SKB) introduced ideas for a continuation of research work initiated by SKB in Greenland. Two projects have taken place to date: the Greenland Analogue Project (GAP) and the Greenland Analogue Surface Project (GRASP). GAP focused on ice-sheet processes and hydrological and hydrogeochemical conditions below an ice sheet, whereas GRASP focused on hydrological and biogeochemical processes in the periglacial landscape in front of the ice. Whilst knowledge on processes associated with glacial and periglacial landscapes has increased significantly as a result of these projects, knowledge gaps remain. SKB is therefore planning a new initiative aimed at addressing these remaining knowledge gaps through international collaboration between the nuclear waste industry and the academic world. The intention is to form an international network of permafrost experts, with a particular focus on hydrology in the periglacial landscape and site-specific modelling, although model code development will be outwith the scope.

Three key questions have been identified to date that could form the main work programme packages (these are open for discussion):

1. Connecting the glacial and sub-glacial hydrology with the periglacial hydrological system on a landscape scale. This work package focuses on how the sub-glacial hydrological system connects to the hydrological system of the periglacial landscape today. To answer this question, we need to know how and where water leaves the sub-ice system, i.e. where along and in front of the ice-sheet margins there are taliks through which groundwater can flow.

2. Permafrost hydrology in a low-relief landscape. As the study area for the GAP and GRASP projects has a more pronounced topography than the area of the planned repository for spent nuclear fuel in Forsmark, important questions remain unanswered regarding the hydrology of low-relief permafrost areas. Comparing studies from the GRASP project with similar studies from low-relief sites in continuous permafrost (such as the Toolik lake/Imnanavit creek area, Barrow environmental Observatory, Cape Bounty) could give some insight.

3. Permafrost transition periods. From the GAP and GRASP projects, great insights into hydrology of continuous permafrost landscapes were gained, but understanding of changes in hydrological flow and transport conditions during the transitional period and over a climatic gradient from no permafrost, via isolated, sporadic and discontinuous permafrost still needs to be improved.

Several potential sites have already been identified, in addition to Two Boat Lake that was the focus area for the GRASP project. These include sites in Alaska and the Northwest Territories in Canada.

It is intended that there will be annual meetings of the expert network, hosted by SKB, with additional interim meetings and workshops as needed. Several PhD students will be funded to undertake the research with funding being provided by the nuclear waste organisations within the network. Other

groups/experts may also be funded to support their involvement, as appropriate. The intention is for three or four PhD students to begin work in September 2019, with a core group meeting taking place in April 2019. Posiva, NWMO and RWM have already expressed interest in taking this forward, alongside SKB, but others are invited to express interest in either funding a PhD or paying a member fee to support the project by the end of 2018.

2.6 CHARACTERISATION OF LANDSCAPE EXPOSURE OBJECTS USING DIGITAL TERRAIN MODELS

Ryk Klos (Aleksandria Sciences) provided an update on the use of digital terrain models to help inform areas for consideration in exposure assessment modelling. The work draws on research undertaken on behalf of SSM and STUK in review of the definition of biosphere object areas in the context of groundwater discharges to mires.

Since the original BIOMASS methodology was developed, there has been considerable experience gained within site-specific programmes of using site characterisation information to support detailed Site Descriptive Models (SDMs). Such models are, in turn, used to support the representation of the biosphere on long time scales within the consequence analyses. A range of techniques is available for drawing on SDMs to support projections of landscape development. Digital terrain models form an elementary part of any SDM and have potential to support understanding of projected catchment/sub-catchment characteristics when coupled with analytical tools available in Geographic Information System (GIS) software. Such tools support the definition of:

- watershed boundaries, which help to define potential model domains;
- preferential flow directions, which help to define near-surface drainage routes; and
- local topographic minima, which help to define potential lake and wetland locations and characteristics.

If the present-day landscape provides a suitable analogue to future conditions, then this sort of analysis provides a good basis for defining areas of interest for consequence analysis. Characteristics of human communities can then be based on an understanding of the landscape, including actions such as emplaced drainage. Potential exposure group (human) and potentially exposed population (biota) characteristics can then be defined within this broader context.

Probability distribution functions (PDFs) of sub-catchment areas within the landscapes at Olkiluoto and Forsmark were then presented in comparison to ‘biosphere object’ areas used in assessments. The analysis demonstrates that the biosphere object areas used in assessments appropriately represent small sub-catchments within the broader landscape context at each site.

The potential for using digital terrain models to define representative drainage networks was also presented, based on analysis of the Olkiluoto landscape.

Potential text for an appendix to the updated BIOMASS methodology describing the potential use of digital terrain models in support of defining biosphere areas of interest for exposure assessment modelling is being prepared for review.

Discussion

In discussion, it was noted that the resolution of the digital terrain models is reduced for areas at Forsmark and Olkiluoto that are currently covered by the sea, but that are projected to emerge from the

sea in the future. It was also noted that the landscape and regolith modelling for Forsmark identify flood plains in the future landscape that are not present today. Potential limitations of making projections over long time scales based solely on landscapes that are present today, therefore, need to be acknowledged.

2.7 ARID LANDSCAPES

Mike Thorne (TST) gave a summary of material developed around arid landscapes, with a focus on Yucca Mountain in the USA and El Cabril in Spain. Arid landscapes are hydrologically interesting since there can be considerable differences observed between dry and wet years. For radionuclide transport, downward transport to the saturated zone followed by lateral transport within the saturated zone need to be considered. The two examples have considerably different saturated zones. At El Cabril the saturation zone is of approximately 60 m depth whereas at Yucca Mountain it is around 600 m.

Text has been developed around both examples for inclusion in an appendix focussing on arid landscapes. There is currently lots of technical detail and this may need to be reduced. The material will be distributed to all project / WG6 participants for comment and will be revised in light of the comments received.

Discussion

Nagra is understood to be starting some work that aims to identify past climate conditions and events that have resulted in valley formation in Switzerland. This would be an interesting example to reference, if it is available by mid-2019.

2.8 POTENTIAL EXPOSURE GROUPS

Lise Griffault (Andra) provided feedback from a questionnaire on the selection and representation of potential exposure groups (PEGs). The questionnaire was comprised of a set of five overall questions. A summary of responses was presented during the fifth project workshop and no additional responses have been received. Some clarification points need to be followed up with those that have responded. Some of the key points arising from evaluating responses are as follows:

- Timeframe is important in driving the description of the system. Typically, a sequential approach is taken to describing the system over time, but calculation cases may then focus on particular snapshots.
- Where climate evolution is of interest, this tends to drive new investigation programmes around analogue sites.
- PEGs largely depend on land-use and water-discharge characteristics, and the geosphere-biosphere interface (GBI) tends to be an object for detailed investigation. Discharge areas need to be clearly defined and justified, irrespective of whether discharge areas are natural or are focussed around pumped groundwater extraction.
- For generic assessment stages, some organisations consider various GBI's to inform model development and calculation cases and the BIOMASS examples have been useful for some organisations in generic stages of assessments. There is however no 'one approach fits all' solution to defining PEGs and so there is no one single 'reference biosphere' that can be considered appropriate. Rather, the BIOMASS methodology must be adapted to individual site/assessment contexts.

- Consideration of the natural productivity of the system is a new approach that should be captured in the enhanced methodology. Urban human activities are also now being considered by some organisations due to public interest.
- Several PEGs may be defined in assessments to explore different pathways. These are usually applied across the various calculation cases. The PEG habits are commonly based on national survey data, although carbon intakes and historical records have also been used. Extreme behaviours for human PEGs are excluded from assessments and uncertainty analysis is not normally performed around habits.
- The BIOMASS methodology focussed on groundwater as a transport pathway for radionuclides to the surface environment and there may be merit in expanding this to include gas transport pathways in the enhanced methodology.
- Some organisations calculate infant and child exposure in addition to adult exposure, which requires new food pathways to be considered to account for their consumption habits, which may merit some discussion in the enhanced methodology. Embryo exposure may also merit consideration.
- It is common practice to aggregate similar food items. Furthermore, many organisations consider that all produced food is consumed, but some apply dilution factors to account for additional resource requirements, which is consistent with present-day habits. Such assumptions are therefore appropriate for shorter timescales, but there may be a driver for a more conservative approach to representing consumption habits for longer timeframes to account for associated uncertainties.

Discussion

SSG-23 clearly states that different types of models are required to build confidence and this argument could be extended to human PEGs with multiple approaches being applied to give added confidence. This could include the use of a carbon-based approach to defining intakes in addition to the use of national survey data. It would therefore be useful to capture in the methodology the fact that there are different approaches that can be applied and that use of more than one approach may help in building confidence. Care should be taken, however, to avoid recommending any specific approach over others.

A summary of the questionnaire responses will be captured in the enhanced methodology within an appendix, which may be useful to assessors when thinking about PEGs.

Some reworking of sections 4.1 and 4.2 of SKB R-18-02 was suggested during discussions. When selecting a PEG it is important to first define the outlet (i.e. the area of interest) and the flow of these sections should make this clear. Both sections are also closely linked with section 3 on quantitative description of the biosphere and spatial areas of interest to support site-descriptive modelling. Section 4.2 is focussed on exposure modelling and should therefore follow section 4.1 on defining the assessment endpoint (PEG). One option to improve clarity would be to include a PEG definition within the conceptual model section rather than PEGs being treated separately. Clearer forward and backward links throughout sections describing the method may also be useful.

Experience has shown that there can be benefits in terms of communicating results if the number of people exposed is placed in context. For example, Posiva, in their 2012 license submission, were required to assess consequences to the wider population, with doses being required to be less than

10% of the dose to the representative person. This consideration of exposure across the population could be included as an example.

For chemotoxics the approach to assessment may be very different. For example, rather than looking at a PEG, groundwater compliance points may be the focus point. The gas-transport pathway may also require alternative approaches to be taken. A narrative approach could be taken to address these points.

The position of exposure group identification and definition within the revised methodology was discussed. It was concluded that it forms part of the conceptual model development and should, therefore, be moved from its location in the Interim Report to sit within the appropriate section of the methodology.

2.9 SELECTION PRINCIPLES FOR POTENTIALLY EXPOSED POPULATIONS OF BIOTA.

Karen Smith (TST) gave a summary of draft text developed around the selection of potentially exposed populations (PEPs) of non-human biota and their representation for assessment purposes. Biota dose assessment approaches were in their infancy when the original methodology was published and no specific guidance on biota dose assessments was therefore included. Some initial draft material has been developed. The intention has been to be concise, referencing out to appropriate methods and sources of information. The focus has been on the ICRP Reference Animals and Plants (RAPs) approach, but with some discussion around ERICA as a user-friendly tool for dosimetry, both in generic and site-specific stages of assessment.

Criteria applied to the selection of representative species for assessment purposes have been collated from several examples and some guidance provided as to how these can be represented in assessments as either user-defined organisms or by mapping to RAPs/reference organisms. Selection of appropriate exposure scenarios and approaches to addressing the spatial requirements of PEPs relative to the area of interest are also discussed.

The draft text is to be distributed to project/WG6 participants for comment. In review, suggestions for additional examples and reference sources are invited, along with suggestions for additional assessment aspects that should be captured.

Discussion

No specific appendix is considered necessary for biota dose assessment. Rather, the text around defining and representing potential exposure populations should refer out to appropriate methods and guidance (including that being developed in WG3). There are also several IAEA documents that should be referenced, including the updated SRS-19, once published.

Throughout the methodology it will be necessary to ensure biota assessment requirements are appropriately captured, such as ensuring biota assessment needs are mentioned in relation to site characterisation.

2.10 ANDRA'S APPROACH FOR DEFINITION OF POST-CLOSURE SCENARIOS IN THE "2015 FRENCH SAFETY OPTIONS DOSSIER" OF CIGÉO

Lise Griffault (Andra) presented an overview of the 2015 Cigéo safety dossier with a focus on the selection of post-closure scenarios.

The Cigéo facility is based around passive safety such that no intervention is planned after an initial post-emplacement monitoring phase. The repository will have a footprint of around 4 km by 3 km and will be situated in a rural location with low population density.

A range of possible evolutions of the repository are required to be considered to demonstrate that the fundamental objective of protecting people and the environment can be met over the long-term. In defining the scenarios, there is a requirement to take account of international practice. This led to a normal evolution scenario being defined, along with altered evolution and "what-if" type cases. Inadvertent human intrusion cases have also been considered. Each case is a simplified description of how radionuclides from the waste may reach people and the environment.

For the normal evolution scenario, two approaches have been taken. A reference situation is based around the best scientific and technical knowledge and representation of the "as designed" performance of the repository. This is then complemented by a "bounding" case, which includes conservative assumptions and data to present a less-favourable case, but still based on the normal evolution of the repository.

A range of risks and uncertainties have been analysed, including uncertainties around input data, characteristics of components (e.g. failure of vertical seals and time of occurrence of such failures), processes governing evolution of the repository and technological uncertainties. The impact of external events such as changes in climate and human intrusion events have also been evaluated.

There is no natural groundwater discharge in the region of the facility and, therefore, a groundwater pumping outlet is assumed with the biosphere model being built around this outlet. The same PEG assumptions are then applied for both reference and bounding situations and, as would be expected, a higher dose was calculated for the bounding case. Whilst this was an expected outcome, the presentation of both situations was useful in illustrating the safety margin.

Andra is now in the process of preparing scenarios for a preliminary safety report that will be part of the licence application. Scenario definition will take account of issues raised during reviews, such as quantification of identified scenarios and inclusion of more "what-if" cases to demonstrate the robustness of the disposal system.

Discussion

Different terms are applied to scenarios (e.g. normal evolution or reference situation). In the enhanced methodology the IAEA safety glossary should be consulted with consistency maintained throughout.

2.11 SAFETY EVALUATION SFL (SE-SFL)

Ulrik Kautsky (SKB) presented.

A conceptual study (SE-SFL) is underway for the disposal of intermediate level waste (ILW) within a new geological disposal facility in Sweden, comprising historical wastes and waste from nuclear facilities. The historical wastes present a real challenge in that the inventory is not fully known. Unlike spent nuclear fuel disposal, releases from the SFL facility are anticipated to occur with releases, which may be relatively high as compared with spent nuclear fuel disposal, occurring quite early.

A coupled source-near-field-far-field-biosphere model has been developed. This is the first time such a model has been applied in assessments by SKB. A lot of sensitivity and uncertainty analysis work has been undertaken to develop understanding around the conceptual system and to identify where data gaps matter. No site has been selected for the disposal facility, but data from the Laxemar site are being

used to inform the assessment, ensuring a self-consistent data set informs on needs for site-specific data.

Several biosphere objects have been considered, including mires, agricultural land, open sea and lakes. Objects from Laxemar are being compared against similar objects at Forsmark to inform on what differences there are and the reasons for those differences.

Preliminary analysis has indicated that Cl-36 is the dominant radionuclide governing exposures associated with agricultural land objects, although in some objects Tc-99 and Mo-93 dominate. In aquatic systems C-14 dominates. The preliminary analysis has also indicated that dose is inversely correlated with regolith thickness. Different climate states have also been investigated. Results indicate that the current climate conditions give rise to the highest doses.

An assessment of the properties affecting dose has been undertaken, based on the preliminary analysis. Results indicate that, as object area increases, dose decreases. Dose also decreases as the thickness of regolith layers increases. It is important, however, not to make sweeping generalisations since the behaviour of radionuclides can vary considerably. For example, thin regolith layers result in a low Mo-93 dose whereas thick layers are associated with low Tc-99 doses. The differences arise because of the different sorption properties of Mo-93 and Tc-99.

Models have been developed to represent different stages associated with landscape evolution. Results have shown that size does matter with larger objects having reduced doses. Results also show that well scenarios do not usually give rise to the highest doses in this context.

The assessment steps taken largely follow the BIOMASS approach. Data were available from previous site studies, but the application of these data was not a simple process; site understanding was central. Experience has shown, from this and previous studies, that various aspects of assessments can continue in parallel rather than assessments being approached as a step-by-step process. As knowledge increases, this triggers new needs and considerations. The assessment context may also be redefined or revised as the assessment progresses (e.g. assessments triggering design change).

2.12 LANDSCAPE DEVELOPMENT MODELLING

Lauri Parviainen (Posiva) gave a brief overview of the modelling of landscape evolution that has been undertaken by Posiva for Olkiluoto Island. Rivers and lakes are not currently present on the island but are expected to form with continuing post-glacial land uplift. The modelling work undertaken in support of the 2012 construction license submission by Posiva has been updated for the operational license submission that is under development. Lake sedimentation has been revisited with new data from site studies being incorporated in models. As a result, whilst a river is still evident when modelling landscape development into the future, it is not as prominent as in the 2012 submission due to increased sedimentation. The development of lakes has also been affected – whilst lakes still form, they are more readily infilled to create new land areas.

The example illustrates how site characterisation can affect site understanding and could be a nice example to include in the enhanced methodology.

2.13 UPDATE ON SITE CHARACTERISATION ANNEX

Ari Ikonen (EnviroCase) gave an overview of developments relating to an annex (or annexes) on site characterisation.

There are multiple needs in terms of site characterisation (e.g. supporting long-term biosphere assessments, environmental impact assessments etc.) and these needs should be considered in the early stages of planning. Whilst the various needs are recognised, the focus of the annex will be on how site characterisation supports biosphere assessment. The benefits of considering the needs of other related assessments will be highlighted. It is also recognised that there may need to be site characterisation undertaken at analogue sites, but the drivers for this will differ from the main site characterisation activities. This should capture the point that analogues are not perfect in this context and that the site itself is an analogue for its future characteristics. The current plan is to consider analogue sites in a separate annex. The target length is between 10 and 15 pages in total.

Wherever possible, reference will be made to appropriate sources of more detailed information within a structured bibliography (e.g. references being grouped according to topic). The current focus is on Nordic experience, but additional examples and references are invited.

The draft outline of the annex is as follows:

- ☐ The background story, 'setting the stage'
  - Relationship to the overall assessment flow
  - Characterisation questions and data needs
- ☐ Methods and tools
  - Examples of systematic mapping, and link with 'landscape statistics' and identification of focal areas
    - General characterisation and monitoring strategy
- ☐ Characterisation of Swedish and Finnish sites at different stages of repository programmes
  - Look into the history (starting from feasibility studies in the 1970s), from generic ideas to multiple sites and to site selection and detailed characterisation
  - What was the motivation, what was the overall plan, illustrative examples (NB. link to the development of the models, data needs and selection criteria and other questions)
  - Bibliography tables
- ☐ Discussion: bridging with the assessment (incl. bottom-up interaction matrices/FEPs), use of stable elements as proxies of (long-lived) radionuclides, role of literature information, uncertainties of the site characterisation results, and other remarks, such as the use of stable element data to support data needs and the role of literature sources of data.
- ☐ Bibliography and references

The structure of the bibliography is to be decided. It could be focussed according to topic or by repository stage.

The analogue site annex will have a similar stage-setting section, but the content will differ. A periglacial example will be included (the Greenland analogue site), and Posiva's reference area approach to

addressing present-day biotopes (in farther surroundings) that are not currently present at the site, but expected to occur with landscape evolution, will also be captured.

The annexes will be further developed and distributed prior to the next interim meeting.

Discussion

In addition to characterisation of current sites, some information should be captured in the annex on the collection of paleoenvironmental data to support understanding of how the site has developed into its current form, to inform on possible future developments. Data collection would be on a regional scale for this purpose, wider than the area of interest of the site. The site characterisation programme is not only about developing an understanding of the site in support of biosphere assessment in that it also develops total system understanding.

Site characterisation is a stepwise process with assessments informing on data needs, those needs being addressed through the site characterisation programme and further assessment identifying additional data needs. Site characterisation is therefore a continuous programme which should be captured. Data freezes may occur to allow assessments to progress through supplying solid datasets, with the output of assessments then informing on additional data requirements.

The focus of the annexes should possibly be around the extraction of data and other information from site characterisation programmes as input to assessments rather than focussing in too much detail on the programmes themselves. It should cover aspects such as how site characterisation programmes inform on model development and how model development then interacts with the site characterisation programme. Figure 4 of SSG-23 provides a nice example of the essential link between assessments and site characterisation programmes. SSG-23 also provides useful information around the quality of site characterisation data and other related topics that could be useful in developing the annexes.

2.14 NEA FEP LIST: IMPLICATIONS FOR THE ENHANCED BIOMASS-2020

Graham Smith (TST) presented a summary review of the NEA FEP list.

FEP lists support the recording of features, events and processes potentially relevant to the post-closure safety assessment. Interaction matrices can then be developed that record how FEPs are carried forward into scenario and conceptual model development. FEPs excluded from assessment should be recorded, along with appropriate justification. FEP lists can also be used as useful quality assurance tools, providing a means by which checks can be made to ensure that all the information made available to the assessment has been taken into account. Together with IM's, a transparent presentation of what has been done with information can be made, which can be valuable for stakeholder communication. It is important to recognise however that assessment contexts can change through the various stages of assessment and rejection decisions around FEPs may therefore need to be revisited.

A FEP list was included as an annex to the BIOMASS-6 report and was intended as a tool to support the development of system understanding rather than focussing on dose: once an understanding of the system has been developed, the behaviour of radionuclides within that system could be considered, for example through an IM.

The NEA has also developed a FEP list (document NEA/RWM/IGSC(2015)11, dated 20 November 2016). The list includes a section on biosphere FEPs, which includes the geosphere-biosphere

interface. There is a lot of commonality between this version and that developed during the BIOMOVS II programme (which formed the basis for that included in the original BIOMASS methodology).

A draft version 3 NEA FEP list (May 2018) has been made available but cannot be referred to at this time. This list has been reviewed. It includes biosphere factors and several sub-factors, including the surface environment, human characteristics and behaviour, contaminant migration and exposure factors.

There are several things to consider in terms of FEPs and the enhanced BIOMASS methodology.

- The structure of FEPs in BIOMOVS II was based around assessment at that time and the contents were considered to be relevant to site characterisation programmes. There has been considerably more experience gained since this time. It may therefore be appropriate to reference out to the NEA FEP list as a source of potentially relevant information that is more up-to-date.
- Thought needs to be given as to whether the structure of the FEP list helps guide thinking around site characterisation.
- FEP lists are potentially useful as a tool to support assessments, particularly when used in conjunction with interaction matrices and as a means of quality assurance. However, there is a risk that, if starting with FEPs, an assumption could be made that the lists are complete. This may not be the case and it may therefore be more appropriate to start with site characterisation and use FEP lists as a check on comprehensiveness. Site characterisation is also required to provide information in support of FEPs for assessment purposes. For example, SKB used system understanding to develop interaction matrices that then fed into a site FEP list, which could be used as an example that others could use as the basis for evaluating what may be relevant to their systems.

There is an opportunity to comment on biosphere aspects of the version 3 FEP list. This could help influence the structure and content to help ensure it meets the needs of the assessment community.

Discussion

The agreement was reached that both generic and site-specific FEP lists that are readily available will be referred to in the methodology, rather than directly including a FEP list. There will be no preference given to the use of one list over another. Information will also be included on how FEP lists can be used to support biosphere assessments.

2.15 RELATING CONCEPTUAL MODELS IN TIME-INDEPENDENT AND TIME-DEPENDENT BIOSPHERE MODELLING

Mike Thorne (TST) and Ryk Klos (Aleksandria Sciences) presented.

A transparent procedure is required in moving from a conceptual (e.g. interaction matrix, IM) to a mathematical model. The procedure should be applicable to both time-independent and time-dependent biosphere models.

Compartment models are typically used to represent contaminant transport in the biosphere with time dependencies being represented by transfer rates between compartments. Such models can be thought of in terms of the movement of entities, rather than focussing on radionuclides (i.e. they can be used to represent the movement of contaminants, but also mass, temperature and momentum).

Compartment models can therefore be used to represent both changes to the environment and the movement of contaminants through that changing environment.

The lead diagonal elements (LDE) of an interaction matrix should be mapped to one or more compartments of a model and each compartment should have one or more properties associated with it, such as mass or contaminant content. The disaggregation into compartments can inform on the need for sub-models where separate sub-models may be used to represent weakly coupled sets of compartments. The IM off-diagonal matrices then become equations that represent the mathematical relationships between donor and receptor compartments. This process is illustrated in Figure 4.

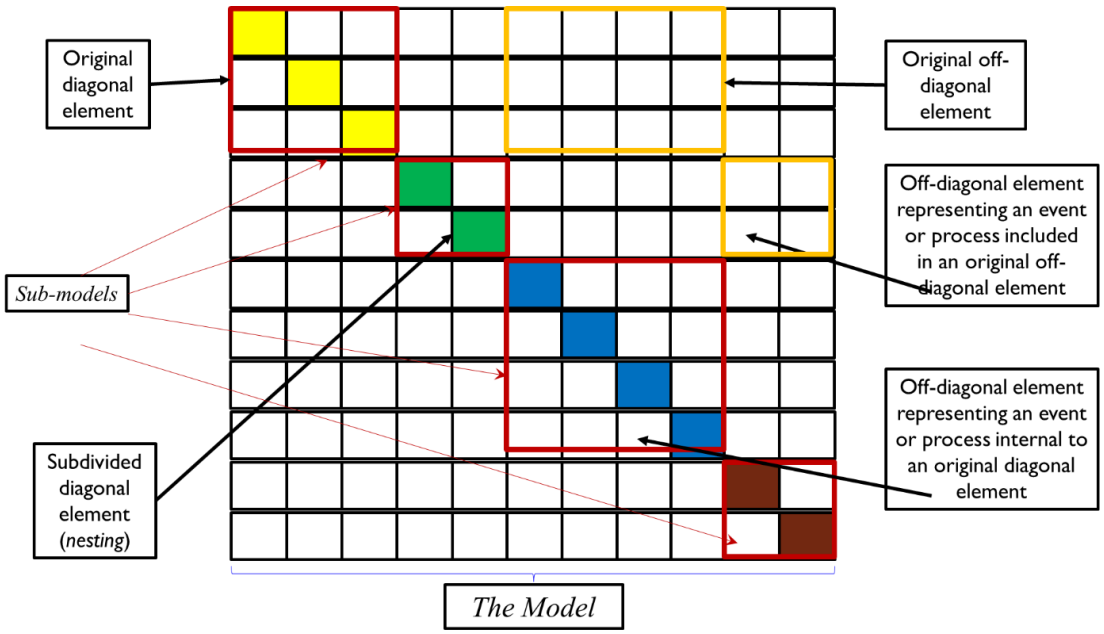

Figure 4. Process for the development of a mathematical compartmental model from an interaction matrix.

Text is to be developed around the basics of compartmental models to bring together background information that could be useful to those new to the field. This will include information on how to represent time-dependent systems within models, identifying potential pit-falls such as time-dependent rate constants. The need for consistency in the methods used to move masses and contaminants across compartments should also be captured. It will be important when developing information around this topic to ensure that recommendations are not made as to the approach to be taken. It may, therefore, be appropriate to write detailed information for publication elsewhere with reference then being made to this source.

Discussion

Interaction matrices are not always used as the basis for mathematical model development. For example, SKB used IM's for developing process understanding, which can help in focussing on where mathematical representation is required, but they then illustrate the mathematical model for each biosphere object with a flow diagram. An IM approach can, therefore, be used to demonstrate completeness in understanding, with flow diagrams then being used to support model development. Screening between an IM and a flow diagram can be used to ensure the model adequately represents the supporting understanding. It is, therefore, a staged process. There is already some discussion

around this in the enhanced methodology, but checks should be made to ensure the staged process is captured.

Interaction matrices can also be useful as a means of ensuring all pathways are identified. They can be used as a first stage in ensuring a comprehensive understanding of the system and for transparently screening FEPs in or out.

Many of the points captured in discussion are covered by the text that has been developed so far, but some additional thoughts could be added to Appendix A. The text developed to date is therefore to be reviewed to ensure that the different ways of using IM's are captured, along with lessons learned. Various examples to illustrate the use of IM's are to be considered. Clear links between Appendix A and the main text are also required.

2.16 SHORT-TERM RELEASES

A draft section on short-term releases has been prepared and an overview was presented by Mike Thorne (TST). The note sets out an approach to considering short-term releases.

Contaminants are treated as tracers in models with the assumption that the system is not affected by the contamination. An approach has been developed for a pulse release within a constant biosphere. It is based on simple equations, with pitfalls highlighted. It is intended that the section could be included as an appendix. The draft will be distributed to invite comment and feedback.

Discussion

It was noted that the National Dose Assessment Working Group (NDAWG) has done some work around short-term releases, which includes some examples. Reference to this may be useful.

2.17 DATA PROTOCOL

Revisions to a figure on data application in models were invited during the last interim meeting. Russell Walke (TST) presented a revised version of the figure (Figure 5) for discussion. The objective for data application is to focus on what matters.

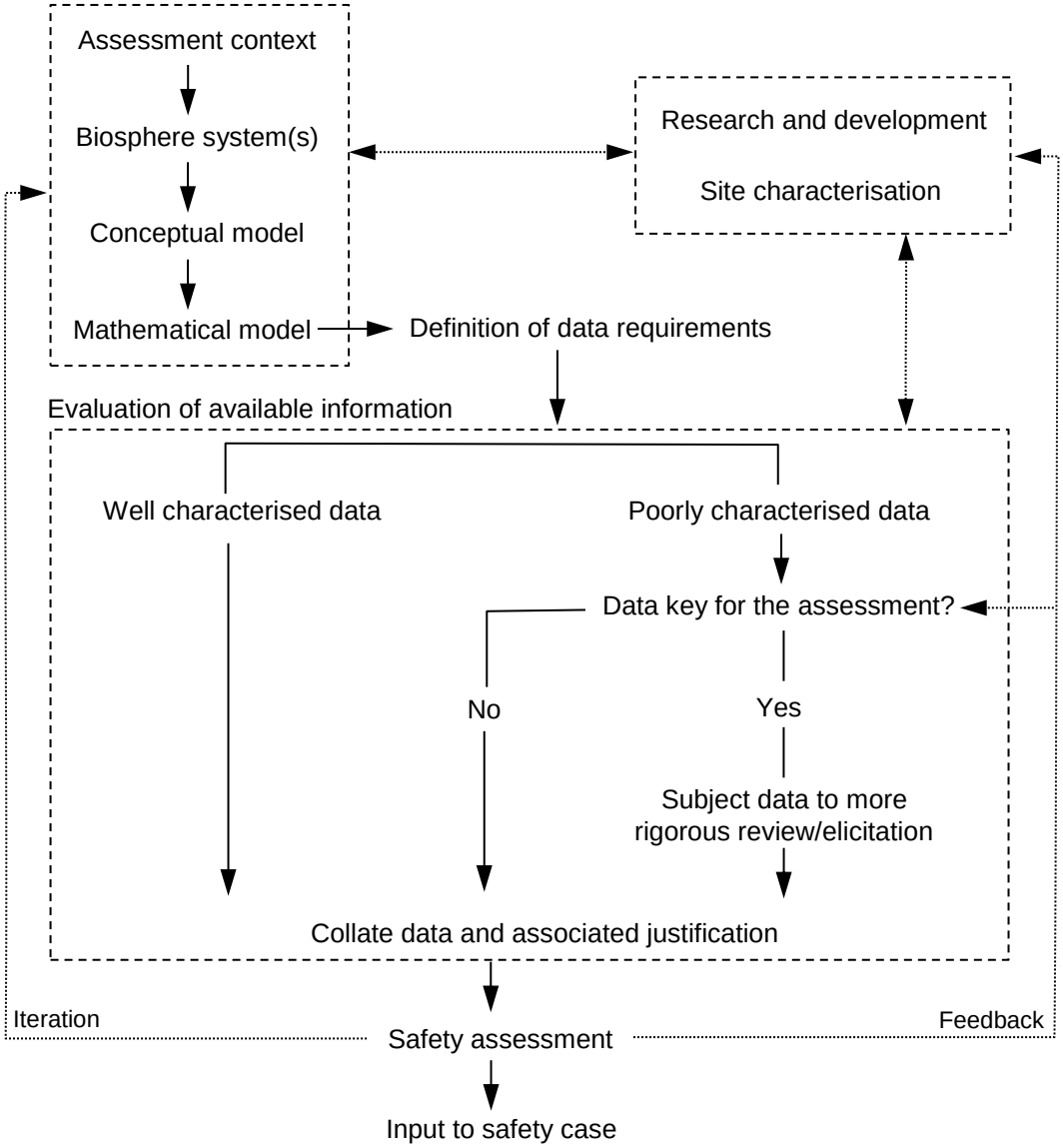

Figure 5. Data application in models – revised version for discussion.

Comments on the revised version were as follows:

- The figure no longer includes reference to prescribed data. This should be brought back in (use of some data may be prescribed by regulations), but without specific reference to datasets such as those of ICRP.
- The figure is to be set within the biosphere methodology so should refer to exposure calculation rather than safety assessment, which is wider. The term exposure calculation was preferred over dose calculation. Whilst agreement was reached that it should be exposure calculation rather than safety assessment, it is important to capture within the text that there is a wider assessment and that common data may apply throughout.

- Thought should be given as to whether input to the overall safety case can be represented in the figure.
- After reference to data being rigorously reviewed there should be yes/no output with 'no' feeding back to research and development.
- Judgement will be required as to whether data are well characterised or not. Reorganisation may be appropriate so that whether or not data are important for assessments is evaluated prior to judging whether those data are fit-for-purpose. This was considered, however, to already be captured in the evaluation of available information that sits around the data qualification process. Whether or not some data are key for assessments will not be known until some assessment has taken place. This is largely captured by the addition of sensitivity analysis and review of assessment within the figure, but some additional supporting text may be useful around the points raised.

2.18 DATA, UNCERTAINTIES AND KNOWLEDGE QUALITY – FITNESS FOR PURPOSE

Ari Ikonen (EnviroCase) gave an update on the development on an annex covering data, uncertainties and knowledge quality. An outline of the annex was presented. The aim in developing the annex is to reference out to more detailed sources of information.

Data and models used in assessments must be fit for purpose (rather than well characterised) and be transparent and traceable. The focus should be safety relevance. To evaluate data as to whether it is fit for purpose, the evaluation approach used should be aligned to the context. The evaluation approach is also, therefore, required to be fit for purpose. As noted previously, some data may be prescribed, but even prescribed data can be captured within data evaluation approaches since these also need to be fit for the purpose.

When selecting data for various modelling tasks, it is important to have the purpose in mind. For example, where sensitivity analysis is to be performed or if the focus is on optimisation, use of conservative values should be avoided due to the undue bias introduced, whereas, where the focus is on demonstrating compliance against a set value, the use of conservative values may be appropriate. Keeping in mind the purpose of assessment when selecting data should be made clear at the start of the annex.

Sensitivity analysis will be included in the annex as a means by which 'what matters' can be identified. Uncertainty analysis can then identify whether or not what matters is uncertain or not. The figure discussed in Section 2.17 should capture the link through to uncertainty analysis. Ultimately, the whole BIOMASS methodology is aimed at managing uncertainty.

2.19 MODEL APPLICATION AND EVALUATION OF RESULTS

Russell Walke (TST) presented.

Assessments can involve a large number of calculation cases, aimed at exploring uncertainties, both in terms of future evolution and in terms of conceptual, mathematical and parameter uncertainty. The variety of calculation cases can be complex to present and a manageable sub-set of cases needs to be identified that sufficiently explore and demonstrate safety. Continuing to reference back to the assessment context is important in helping to maintain focus and clarity.

Not all cases will necessarily require dose to be calculated. For example, contaminant transfer fluxes from/to specific receptors could be of interest. This may be particularly relevant in informing decisions

on, preferred design, for example. Irrespective of the endpoint taken forward, the structure of advice in the methodology should be applicable.

Results from calculation cases should be subject to appropriate evaluation. This should consider whether the results are intuitively correct. Any unexpected results should be reviewed. This should include consideration of whether input files are being used as intended. Independent checking can be useful. Version control should be maintained, both in terms of input and output as well as software versions used. There should be further iteration of calculation cases until there is confidence in the model results. Only at this stage should the results move through to supporting the safety case.

In presenting results, the target audience should be considered. Where possible, consistency should be maintained in the way that output is presented (e.g. consistent figure layouts, including the scales used to present results) and perspective should be maintained – care is needed when presenting very small results. It may be appropriate to extend past the presentation of results relative to some criteria, by presenting information specific to key radionuclides and exposure pathways. Complementary safety indicators should also be discussed. Examples on complementary safety indicators can be drawn from both Posiva and Yucca Mountain assessments.

Probabilistic assessments are increasingly required. There is experience and examples that can be drawn from when developing guidance. The guidance will be developed for review prior to the next interim meeting.

Discussion

The presentation of results in a spatial scale (i.e. use of maps) can be an issue. People may interpret the information as fact that impacts will be exactly where shown. This could result in concern amongst the affected population and loss of public confidence. It is vital therefore that the target audience is considered when deciding on the appropriate means by which results are presented. The use of interactive figures is being explored in some programmes which may be appropriate to capture.

2.20 DISCUSSION ON COMMON ISSUES IN RELATED IAEA WORK PROGRAMMES

A brief discussion session was held with David Bennett and Andrej Gusgov (both IAEA) to discuss areas of commonality with other IAEA programmes, particularly the Near Surface Disposal Forum and the GEOSAF projects. Both work programmes have clear links with the work being undertaken in WG6 and collaboration would therefore be beneficial to ensure that any new aspects of the BIOMASS methodology are captured in these projects that will both continue past the end of MODARIA II. Organisation of a separate meeting to allow more in-depth discussions of the related work programmes was suggested. Such a meeting would allow not only discussion around technical aspects of the work programmes but would also help ensure consistent use of language and concepts. The time and date for a meeting are to be agreed.

2.21 CLOSING PLENARY

Tobias Lindborg gave a brief closing presentation on the final morning of the meeting that summarised activities and progress during the week.

Interaction with the following MODARIA II WGs is envisaged:

- WG1 – methods applicable to shorter timescales (e.g. longer-term management of legacy sites over 1000 years (similar to near-surface disposal);

- WG3 – ensuring consistency, where appropriate, with guidance on biota dose assessment methodologies;
- WG4 – process understanding linked to data needs and classification of transfer data as a function of climate; and,
- WG5 – spatial scales for biota populations.

3. ACTIONS AND FORWARD PLAN

The BIOPROTA TST is tasked with delivering technical input to the development of the enhanced methodology, which is in addition to the contributions from WG6 members. Review of BIOPROTA inputs to the overall methodology enhancement as well as continued development of new material (e.g. report sections and/or illustrations of specific aspects of the methodology) is very much encouraged from all WG6 members.

To ensure that the material developed is fit-for-purpose, review of the material produced to date by those new to the field is particularly encouraged. Such review will help identify whether the level of information presented is appropriate and whether there are additional aspects that should be addressed. There have been several new areas developed since the publication of the interim report, however, and these, including the latest versions of figures, are to be drawn together within a new iteration of the report by the end of November. This effort will focus on the main report, rather than appendices. Information developed in support of appendices will be distributed alongside the revised main text. Where there are multiple versions of figures, these should all be included to allow feedback to inform decisions on the most appropriate versions to include in the final draft report.

Feedback on the material distributed is requested by the end of January 2019. This will allow comments to be taken into account in a final draft report that is to be produced prior to the next interim meeting in May 2019. Participants are requested to email any comments / suggestions on any aspects of the methodology to the BIOPROTA TST project manager (Russell Walke) and the WG6 chairperson (Tobias Lindborg). This will help to ensure that any points raised are not missed. In reviewing the report (or sections within), terms requiring definition within the report glossary should be identified.

3.1 ACTIONS AND RESPONSIBILITIES

The final task during the workshop was a walk-through of the interim report to identify actions and assign responsibilities, including assignment of reviewers for specific sections of the report. Although individual reviewers have been identified, all other project/WG6 participants are invited to review and provide feedback. The main discussion points are captured below.

3.1.1 Entire main text

All participants are invited to review the interim report (revised version to be distributed by the end of November). SKB and Andra both have people new to the field (**Aimee Aubonet** (Andra) & **Thomas Grabs** (SKB)) and they will be asked to review. **Mi-Seon Jeong** (KORAD) and **Ayeoung Kim** (KINS) offered to review the report from the perspective of being relatively new to biosphere assessment. Review by other regulators would also be beneficial (e.g. SSM and STUK).

3.1.2 Section 2: Assessment context

The assessment context is wider than just the biosphere (i.e. there is an overall safety case context) and care needs to be taken to avoid confusion by the same terms being used in different contexts. It is suggested that reviewers keep SSG-23 at hand during the review process and check for consistency as well as considering the wider safety case. Where inconsistencies are identified, these should be flagged.

Primary reviewer(s): **Tobias Lindborg** (SKB).

3.1.3 Section 3: Representation of the biosphere

Box 2, in particular, was identified as requiring careful review.

Within Section 3.2, thought needs to be given to the terms 'biosphere description' and 'site description' as there can be confusion around this. This could be illustrated by a figure on how the biosphere assessment and the SDM interface with each other.

Primary reviewer(s): **Tobias Lindborg** (SKB), **Alex Proverbio** (LLWR), **Lise Griffault** (Andra).

3.1.4 Section 4: Biosphere modelling

The section is to be revised in the light of discussions during the workshop. However, these revisions will be made for the final draft version of the report, with the exception of the addition of an updated figure that will be added to section 4.5 prior to review. The current version will nonetheless be reviewed with additional comments being captured during revision.

Primary reviewer(s): **Ulrik Kautsky** (SKB), **Lise Griffault** (Andra; particular focus on the sections up until mathematical modelling), **Alex Proverbio** (LLWR; focus on sections 4.2, 4.3 and 4.4), **Ray Kowe** (RWM; focus on sections 4.2, 4.3 and 4.4), Lauri Parviainen (Posiva; Section 4.5), **Danyl Perez-Sanchez** (Ciemat; Section 4.6).

3.1.5 Section 5: Model application and evaluation of results

Section 5 is still to be developed and no review is required at this time.

3.1.6 Section 6: Conclusions

Conclusions are still to be developed. All reviewers are to consider conclusions relating the specific areas they are reviewing. These conclusions will then be drawn together in Section 6. Comments relating to participation in the process should also be provided.

3.1.7 Appendices and examples

The current Appendix A1 is overly complex and will be replaced with a simpler version that will be developed in the light of comments received on the current version during workshop discussions. The section relating to climate will also be updated to include a link to the global climate model discussed in Section 2.4. The section relating to defining the area of interest will also be shortened. Other sections, such as uncertainty analysis, site characterisation and PEGs questionnaire responses are to be developed. Each appendix section will be distributed as it becomes available.

A list of required examples will be distributed by the TST and all reviewers are requested to consider examples that could be used to illustrate specific aspects of the methodology as they review. The aim is to have examples for all steps of the methodology and to cover a range of assessment contexts. The examples should be developed as summaries of work that has been done, or as illustrations, with references provided to where more detailed information can be found.

For each appendix / example, a common introduction could be developed that sets out which part of the methodology the appendix or example is focussed on. Where information is very complex, it may be beneficial to publish separately with reference then made to the material and, if appropriate, a summary of the material being developed for inclusion. This will help avoid over complicating appendices and changing the balance of the overall document. It would also help avoid giving undue weight to one approach over another.

3.1.8 Links to the overall safety case

There are already several links made between biosphere assessment and the overall safety case, but further emphasis is needed. For example, climate modelling is a general safety case issue rather than falling specifically within biosphere assessment, but it is an essential input to both biosphere assessment and the overall safety case. Geosphere modelling also a critical input. No special section covering the linkages is suggested, but there is a need to ensure that linkages are captured in relevant areas throughout, including in relevant figures.

3.1.9 Terminology

Some concern was expressed that the name of the WG has drifted toward a focus on high activity waste disposal. It was agreed that this had not been the intention, with the methodology being intended for much broader application, and efforts will be made to ensure the original intended title will be used at all times.

The term 'FEP handling' is to be used in place of 'FEP screening' since the process is more complex than a simple 'in' or 'out' decision process.

Use is to be made of the IAEA glossary, with additional terms being defined within the report.

3.2 NEXT STEPS

The next joint BIOPROTA workshop / WG6 technical meeting will be held in Munich, Germany in May 2019. To support development of the draft final report for discussion during that meeting, a proposal will be prepared and distributed to BIOPROTA member organisations to invite project funding in 2019. The proposal will be prepared and distributed by the end of 2018.

3.3 OTHER RELATED MATTERS

There is an intention for each of the MODARIA II working groups to publish a summary scientific paper of their activities within a special issue of the Journal of Radiological Protection (JRP). The papers should be scheduled for development by the end of 2019. There is also the possibility of including one or more editorials to set the work in context or development of supplementary and/or opinion papers.

A proposal for a separate JRP special issue on waste management has been made but has not yet been taken forward.

3.4 SUMMARY OF ACTIONS

The following specific actions were agreed and timescales for action are detailed.

	Action	Person(s) responsible	Timescale
1	Distribute list of required examples	Russell Walke (TST)	November 2018
2	Incorporation of new material presented during the workshop within main report, including figures	TST	November 2018
3	Distribution of memo on short-term releases for comment.	TST	November 2018
4	Distribution of text on biota assessment guidance for comment. Distribution to include WG5 and WG3 to ensure consistency with other developing guidance.	TST	November 2018

	Action	Person(s) responsible	Timescale
5	Figure 1-2 to be revised such that PEG and PEP definition is captured within conceptual model development, but without emphasis being lost	TST	November 2018
6	STUK to be contacted with request for review of the main body of the report.	TST	November 2018
7	Update Section 4.5 figure	TST	November 2018
8	Preparation and distribution of a proposal for TST funding in 2019	Russell Walke	December 2018
9	Review of the material within the interim report and provision of feedback and comments	All	January 2019
10	Identification of examples to illustrate steps in the methodology	All	January 2019
11	Provision of examples that can be included in the methodology and provision of summary text/illustration with references.	All	January 2019
12	All reviewers to provide conclusions on the sections reviewed that can be drawn together within Section 6.	All reviewers	January 2019
13	Consideration to be given to incorporating definition of PEGs within the overall development of the conceptual model section to address issues around the flow of Sections 4.1 and 4.2.	TST / Lise Griffault	January 2019
14	Review of Appendix A relating to the use of interaction matrices to ensure different uses are captured.	Ulrik Kautsky (SKB)	January 2019
15	An appendix is to be developed summarising PEG questionnaire responses	Lise Griffault	January 2019 (or soon thereafter)
16	Development of draft guidance around model application and evaluation of results	TST	April 2019
17	Revision of Appendix A1	TST	April 2019
18	Revision of main text in the light of review comments	TST	April 2019
19	Site characterisation and analogue site annex drafts to be developed and distributed for comment prior to the next IM.	Ari Ikonen	April 2019
20	In developing text around the identification of human PEGs, different approaches to defining habits should be captured (e.g. national surveys and carbon intake) and note made that use of multiple approaches may help in building confidence.	Lise Griffault / Graham Smith	April 2019
21	Provision of appendix on defining area of interest	Ryk Klos (Alexandria Sciences)	April 2019
22	Full review of the report and annexes to ensure an appropriate balance through the document.	All	May 2019 interim meeting

APPENDIX A. MEETING PARTICIPANTS

The workshop was attended by the following participants.

Participant	Organisation
Alena Zayazanova	IAEA, Austria
Alex Proverbio	LLWR, UK
Andre Ruebel	GRS, Germany
Ari Ikonen	EnviroCase, Finland
Ayeoung Kim	KINS, Korea
Branko Kontic	Josef Stefan Institute, Slovenia
Carol Robinson	NRPA, Norway
Danyl Perez-Sanchez	Ciemat, Spain
David Bennett	IAEA, Austria
Emma Johansson	SKB, Sweden
Graham Smith	GMS Abingdon, UK (BIOPROTA TST)
Joanne Brown	Environmental Radioactivity Consultancy (ERC), UK
Karen Smith	RadEcol Consulting, UK (BIOPROTA TST)
Lauri Parviainen	Posiva, Finland
Leena Torpo	Fennovoima, Finland
Lise Griffault	Andra, France
Maria Norden	SSM, Sweden
Mike Thorne	Mike Thorne and Associates, UK (BIOPROTA TST)
Mi-Seon Jeong	KORAD, Korea
Ray Kowe	RWM, UK
Russell Walke	Quintessa, UK (BIOPROTA TST)
Ryk Klos	Aleksandria Sciences, UK
Shulan Xu	Xu Environmental Consulting, Sweden
Stephanie Bush-Goddard	U.S. Nuclear Regulatory Commission, USA
Tobias Lindborg	SKB, Sweden
Ulrik Kautsky	SKB, Sweden
Ville Kangasniemi	EnviroCase, Finland