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 Fifth Workshop Held in Parallel with the Second Interim Meeting of MODARIA II Working Group 6

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Version 2.0, 12 September 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 second Interim 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) in Kerava, Finland from 16-18 May 2018, hosted by Posiva. 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), Mike Thorne (Mike Thorne and Associates Ltd) and Graham Smith (GMS Abingdon Ltd) prior to distribution 9 August 2018 to workshop participants and BIOPROTA project sponsors for comment.

Version 2.0. Final workshop report prepared by Karen Smith (RadEcol Consulting Ltd) and Russell Walke (Quintessa Ltd), taking account of comments received from workshop participants and BIOPROTA project sponsors. Distributed 12 September 2018.

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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. It also includes examples of the application of the methodology, called Example Reference Biospheres (ERBs), and associated results expressed in terms of radiation dose rates to humans for unit release rates of a sub-set of long-lived radionuclides. The radionuclides were selected to represent a range of radiological and radio-ecological characteristics and were identified as potentially relevant in post-closure safety assessments of geological disposal facilities for solid radioactive wastes (Nb-94, Tc-99, I-129 and Np-237). With the focus of such assessments being on long-term future biosphere conditions, the methodology was intended to support the development of biosphere models as a ‘measuring instrument’, providing assessment results for comparison with protection objectives rather than as predictions of future conditions and exposures. The BIOMASS work built on initial development of a reference biospheres methodology in the BIOMOVS II collaborative study[b].

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 all the above, it was considered timely[c] 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

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[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] BIOMOVS II (1996). Development of a Reference Biospheres Methodology for Radioactive Waste Disposal. Biospheric Model Validation Study, Phase II Technical Report No. 6, published by the Swedish Radiation Protection Institute, Stockholm, Sweden.

[c] 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.

Assessment (MODARIA II) also commenced in 2016 and had consistent objectives with regards to enhancing the BIOMASS methodology. The two programmes are, therefore, 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, four workshops have been held:

- 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[d].
- 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[e].
- A third BIOPROTA workshop was then held in May 2017 with the first Interim Meeting (IM) of WG6, hosted by ENSI, Brugg, Germany at which progress was reported on assigned activities[f].
- 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[g]; the interim report was finalised after the meeting and published under SKB covers.

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 report will be further developed through collaboration between both projects and delivered through BIOPROTA in 2019 as input to a final report of WG6.

This report provides a summary of the presentations and discussions during a fifth BIOPROTA project workshop, held in conjunction with the second WG6 IM hosted by Posiva in Kerava, Finland in May 2018, that further discussed and built on the interim report.

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.

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[d] 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.

[e] 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.

[f] 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.

[g] 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.

The specific objectives of the joint project workshop and second WG6 IM 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 a wide range of organisations about their on-going interests in this area; and
- to agree on the next steps for the BIOMASS methodology enhancement.

1.2 WORKSHOP PARTICIPATION

The workshop was held in Kerava, Finland, from 16-18 May 2018. The meeting was attended by 33 participants from 9 countries. Participants are listed in Appendix A.

1.3 REPORT STRUCTURE

Section 2 of this report summarises the presentations made by the TST to the BIOPROTA project and other participants on potential areas for enhancement of the BIOMASS methodology. 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 WELCOME FROM POSIVA AND OVERVIEW OF THE FINNISH SPENT NUCLEAR FUEL DISPOSAL PROGRAMME

The workshop opened with a welcome presentation from Lauri Parviainen (Posiva). In Finland, a repository for the final disposal of spent nuclear fuel (SNF) is under construction on the Island of Olkiluoto. A repository for operational radioactive wastes is already in use on the island and is owned and operated by the local nuclear power plant. The operational waste repository is located at a depth of 60 m in crystalline rock.

The concept for the SNF repository is for waste to be encapsulated in copper canisters before being lowered into the repository via shafts. Excavations have already begun for the disposal tunnels and main access tunnel. Drilling for the canister lift is also underway and construction of the encapsulation plant is planned for 2019. A long-term full scale in-situ test will begin this year in which copper canisters containing heaters will be emplaced in a test tunnel at disposal depth, with bentonite backfill. Monitoring equipment will be installed to continuously measure the pH of water, its conductivity etc. After some decades, the tunnel will be opened to allow detailed evaluation of the functioning of the disposal concept.

A safety case is being developed in support of an operational license submission that is due in 2021. This will build upon the construction license submission that was made in 2012. New features of the operational license safety case will be the development of a database containing all data used in safety case modelling. All data within the database are to be quality assured prior to being fixed. There will also be a new interactive management system for the publication of all safety case reports that will allow easy online navigation between reports.

There have been some difficulties faced in the design phase of the repository, requiring methods to be modified to remain cost-effective whilst maintaining safety features. The design phase is due to complete by the end of 2018.

2.2 CO-ORDINATION WITH OTHER IAEA INITIATIVES: OVERVIEW OF IAEA PROJECTS ADDRESSING THE SAFETY CASE FOR DISPOSAL FACILITIES

Gerard Bruno (IAEA) gave an overview of different IAEA projects addressing radioactive waste disposal safety cases. The projects cover borehole, near-surface and geological disposal concepts with working groups having been initiated in relation to each concept to help facilitate the application of IAEA safety standards across Member States.

The IAEA safety standards for radioactive waste disposal require the protection of people and the environment during both operational and post-closure phases. Long-term safety must be demonstrated. The location of facilities should be considered to mitigate against events such as erosion etc. where feasible. Scenarios should be developed to allow the consequences of various features, events and processes to be evaluated. This should include human intrusion with the output being intended to inform optimisation.

The main IAEA projects related to safety demonstration were briefly described, including:

- GEOSAF I, II and III, focussed on international harmonisation of approaches in geological disposal safety demonstration, with phases II and III extending the initial scope to include operational safety and linking this with long-term safety;
- HIDRA I and II on how to address post-closure human intrusion scenarios for near-surface and deep geological disposal facilities; and,
- PRISM and PRISMA that dealt with the different actions needed and arguments to be made at different stages in the evolution of safety cases for near-surface disposal facilities.

A new working group has recently been formed on the use of monitoring programmes in the safe development of geological disposal facilities. The first TM of this working group will take place from 3-7 December 2018. In relation to near-surface disposal facilities, a forum has recently been established. This aims to provide an enduring forum to facilitate the sharing of experience in the development of near-surface disposal safety cases and the development of guidance. A first meeting took place in November 2017 to identify the interest areas of Member States and to define a programme of work for the next three years. Four working groups were established relating to the use of safety cases in decision making, regulatory experience, post-closure safety assessment and communication to different audiences.

Near-surface and geological disposal facilities are considered separately by the IAEA for several reasons:

- safety standards differ, as do supporting safety guides;
- separation helps ensure attendance at working group meetings of those interested in specific topics rather than risking overwhelming meetings; and,
- near-surface facilities are located within the biosphere whereas geological facilities are not and the timescale of interest for safety assessments also differs.

There has been a recent move away from focusing on safety assessments to focusing on safety cases, with the former being concerned primarily with consequences and the latter being much broader in terms of demonstrating overall safety. Safety assessment fits within the overall safety case and covers the radiological impacts on human health and the environment.

It is important to recognise that there is an overall approach to undertaking a safety case and that the various projects within this area aim to work consistently and are linked to each other. The biosphere does not exist in isolation and account needs to be taken of the geosphere. Consideration is needed when using the terms biosphere and geosphere, in case alternative terminology may be better. For example, site characterisation should be used rather than biosphere characterisation.

2.3 WALK-THROUGH OF THE INTERIM REPORT AND FEEDBACK AND REVIEW OF THE UPDATED BIOMASS FLOWCHART

Russell Walke (BIOPROTA TST) provided a recap of BIOPROTA and the project objectives and summarised the 2017 interim report (published as SKB report R-18-02[h]). Emphasis was placed on this being interim and, therefore, a work in progress. Participants at the workshop and others involved in the work programme (BIOPROTA and/or WG6) continue to be invited to contribute on the way the methodology is portrayed in the interim report to allow further development as the work programme proceeds. This is particularly the case for the flowchart for the methodology (Figure 1). The interim report provides one possible format, but there are others and feedback is encouraged to allow a consensus to be arrived at.

An alternative figure for the overall methodology was presented by Ulrik Kautsky. A linear figure of the methodology (as given in SKB R-18-02, Figure 1-2, and reproduced here as Figure 1) is not representative of how assessments are undertaken. A cyclical approach was therefore suggested (Figure 2) [note that the figure presented was intended as an illustration of what could be further developed]. The same 'boxes' are retained from Figure 1, but overall understanding moves to the middle to inform all the different stages of the methodology.

Possible revisions to this figure were discussed with the following suggestions being made.

- The positioning of 'overall safety assessment' could be moved to avoid misunderstanding that the biosphere assessment methodology shown relates to the safety assessment as a whole when it should be clear that biosphere assessment sits within the overall safety assessment context.
- Chemotoxicity could be added to the figure to capture non-radioactive contaminants.
- Stronger and weaker arrows could be incorporated to distinguish the main stream of work. A means of highlighting the start point may be useful. This could be achieved by numbering the steps in the methodology.
- It should be specified why some arrows are unidirectional and others bidirectional.

In discussion it was suggested that both the linear and the circular versions be maintained. The circular version with understanding in the centre was valued, but the interim report version was considered to fit well with the structure of the report in describing the methodology. If both versions of the workflow diagrams are used, the interim report version could be expanded to include some examples of what the expected outcome of each stage should be, to help emphasise the difference between the methodological steps. It would be important to recognise the different applications of the methodology and examples of output should therefore be broad to encompass different assessment types (doses, fluxes, radioactivity, non-radioactive contaminants) and stages etc.

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[h] BIOPROTA (2018). BIOMASS 2020: Interim report — BIOPROTA report, produced in association with IAEA MODARIA II working group 6. Report R-18-02. Swedish Nuclear Fuel and Waste Management Co. (SKB), Solna, Sweden. www.skb.se.

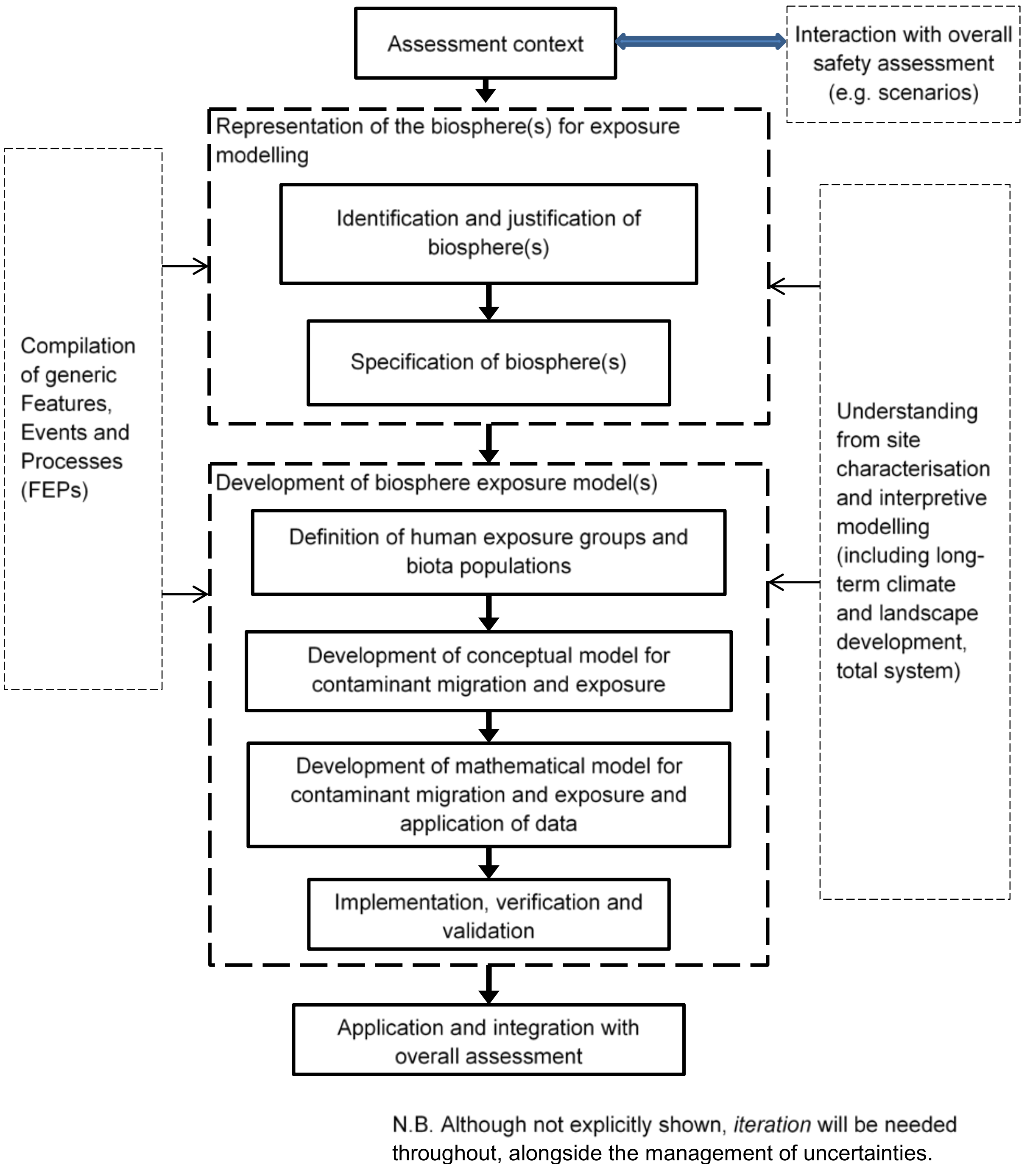

Figure 1. Schematic illustration of the updated BIOMASS methodology (central column) with supporting information and interactions (shown at the sides) [Figure 1-2 from SKB R-18-02].

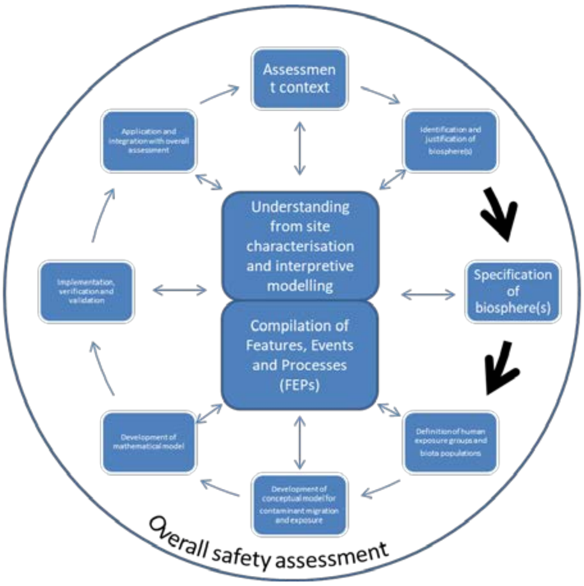

Figure 2. An alternative approach to illustrating the methodology workflow [from Ulrik Kautsky].

The distinction between the biosphere and geosphere in Figure 1-1 of SKB R-18-02 on biosphere assessment within the context of the broader safety case (reproduced in Figure 3 below) may not be helpful, since some may assess the whole system as one or, where near-surface facilities are considered, there may not be a clear distinction. Whether compliance points are in the geosphere or biosphere will vary by country. The figure aimed to emphasise that an integrated approach is needed within an overall safety case and there is a general intent to move away from referring to radionuclides and radioactivity throughout the methodology with contaminants being the preferred term to encompass non-radioactive contaminants. An action was placed on the TST to develop alternative figures for discussion during the next workshop. It will also be important to anchor the report in terms of other IAEA guidance on the development of safety cases (as outlined in Section 2.2) and to ensure consistent terminology.

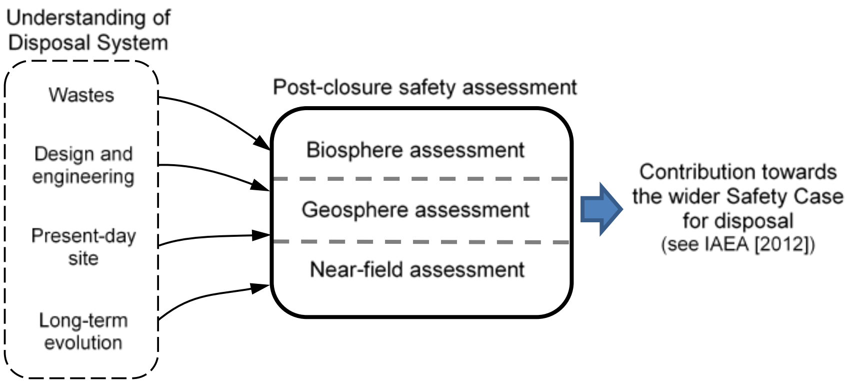

Figure 3. Biosphere assessment within the context of the broader Safety Case (Figure 1-1 of SKB R-18-02).

Overall, the terminology used throughout the interim report should be reviewed and revised, where appropriate, and should be consistent with IAEA terminology and definitions. For example, the suggestion was made to remove 'generic' in terms of FEPs and 'calculation case' is preferred to 'scenario' since it is usually a matter of the overall safety case to evaluate scenarios. Furthermore, it should be made clear at an early stage of the report that the methodology is applicable to various calculation cases; this is currently mentioned in Chapter 3. Throughout it may be useful to introduce text boxes to provide clarification / explanation of the meaning of terms within the context of the methodology. The use of 'buzz words' should be avoided.

2.4 POTENTIAL EXPOSURE GROUP QUESTIONNAIRE FINDINGS AND IMPLICATIONS FOR THE ENHANCED METHODOLOGY

Lise Griffault gave an overview of the questionnaire on potential exposure groups (PEGs) and biota populations that was distributed in 2017 and a summary of the responses received. To date, nine responses have been received from regulators and operators. Additional responses are invited, and the questionnaire will be distributed to all BIOPROTA members, plus other organisations outwith BIOPROTA.

Some of the key responses and implications for the methodology are summarised below.

- The BIOMASS methodology is applied over different timeframes and this leads to some differences in application.
- There is interest in urban environments and exposure pathways rather than just rural, and often agricultural, contexts, which would be a new aspect to consider in BIOMASS.
- For many, the biosphere is not integrated with the near-field and geosphere in terms of models. However, for some, such as Posiva, although models for the geosphere and biosphere are separate, connections are maintained through consideration of human actions affecting the geosphere etc.
- Biosphere models can be site-descriptive models or dose models and there is a need to be clear as to what is meant and to maintain consistency in terminology. The terms 'site description model' and 'exposure model' were suggested with both being explained within the glossary of the methodology.
- Responses have highlighted further terminology issues. For example, 'stylised biosphere' is a term used by one responder in relation to the justified simplification of information from a biosphere-system for the purpose of dose computation, whereas 'stylised' for another responder relates to site-generic assessments. There can, therefore, be different meanings associated with the same word. Further work on response collation is needed to gather together instances of conflicting meanings to inform on the adoption of a consistent terminology.
- Responses indicate that the effect of climate on landscape evolution is included in most instances for post-closure assessments, although, for some, a time-independent biosphere situation is assumed over the period for which post-closure exposure calculations are required. For the operational phase, the current situation is considered in most instances.
- Clear definitions of the geosphere-biosphere interface (GBI) are needed, recognising that a GBI definition will be affected by the assessment context. Environmental change is often considered in terms of the GBI, but this is not always the case. Where site-specific assessments are being undertaken, there tends to be a greater consideration of climate evolution and its influence on the GBI whereas for site-generic assessments there is a greater tendency to consider the GBI in terms

of a well with other generic GBI's potentially being explored. There are a lot of different views relating to the nature, role and significance of the GBI, but it is essentially the discharge from the repository to the surface environment that is used to define the area (and volume) of interest. Where a specific site is of interest, particle tracking may be used to identify outlet points, with PEGs then being defined around these.

- The definition of PEGs for the post-closure phase is largely based around land-use assumptions and, hence, landscape evolution is an important consideration. One approach noted from responses was to use the productivity of the natural system to help define the PEG. In some cases, clear guidelines are available that stipulate what should and should not be considered. For nearly all responders, local habits (and historical records) at the area of interest were used to underpin PEG habits with several using analogue data to represent habits and define PEGs under different climate conditions. However, much of the focus around PEGs relates to groundwater discharge (natural or via wells). Little consideration has been given to PEGs for a gaseous release and this may merit further discussion.

- The original BIOMASS methodology only illustrates exposure calculations for adults, but, for some, national regulations require other age groups to be considered. Some additional guidance to support those with requirements to assess doses to children etc. may therefore be beneficial. It was noted by Graham Smith that there is an ICRP compilation[i] on risks associated with given amounts of exposure for different age classes that could be referenced. The ICRP position is that technically there is only a need to consider adult exposure in assessments. It is recognised that there may be a need to consider exposure of other age classes to improve confidence and address public/stakeholder concerns.

- The aggregation of food groups is quite common practice and there may be merit in considering whether anything can be said on the implications of this for dose calculations. Output from assessments undertaken to date suggest that dose implications are unlikely to be significant. However, there may be stakeholder implications with members of the public wanting to understand the implications of their dietary choices and those of their children. The dose distribution across a population has been evaluated by Posiva in their 2012 assessment, providing useful information on exposure of the population beyond the initial PEG. The assessment was based on population density data for Helsinki that was considered to overestimate the number of exposed persons at the site with the overall assumption of rural conditions.

- Only a few responders have specifically evaluated dose rates to non-human biota in assessments, but the trend for increased consideration was noted. It would be beneficial to include some information on what to do in assessments if benchmarks are exceeded (ensuring the word 'limit' is not used). Explicit evaluation of potential impact on the environment is increasingly required, but biota dose assessments can also be useful in terms of public communication. Some guidance for those starting out in assessments on how to select representative biota for evaluating impacts would be useful.

It was noted that, in the UK, there is guidance available on the selection of human habit data for use in prospective assessments for nuclear power plant discharges. Whether or not habit data for PEGs in

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[i] Data are provided in Annex F, G and H of 'ICRP, 2012. Compendium of Dose Coefficients based on ICRP Publication 60. ICRP Publication 119. Ann. ICRP 41(Suppl.).'

radioactive waste disposal assessments should be consistent with such habits data to avoid unjustifiable distinctions may merit discussion.

A summary of responses (including new responses) will be developed prior to the next TM. New responses (and clarifications on responses received to date) are requested by mid-September.

2.5 PROPOSED APPROACH FOR DEVELOPING GUIDANCE ON BIOTA DOSE ASSESSMENT, INCLUDING SPATIAL SCALES

Karen Smith (BIOPROTA TST) gave a brief update on plans for developing guidance on biota dose assessment for inclusion in the enhanced methodology. Development of guidance on biota dose assessment was halted to allow responses to the PEGs questionnaire, which included questions around biota dose assessment, to be submitted and analysed. Assuming that there is sufficient project funding, it is intended that some text will be developed for consideration and discussion during the next TM.

2.6 AN UPDATED FRAMEWORK FOR MODELLING LONG-TERM FUTURE CLIMATE CHANGE

Natalie Lord (University of Bristol) presented work being undertaken on behalf of SKB and Posiva. The work follows from that previously undertaken on behalf of RWM, which also formed the basis of her PhD thesis. The work is focussed on modelling long-term climate change with a statistical climate emulator having been developed that allows continuous simulations of climate.

There are a range of processes that affect global climate, but the main climate forcings for long-term climate change are orbital variations and atmospheric CO_2 concentrations. Global ice volume and its distribution is not a forcing (being an internal aspect of the global climate system), but is used as such in the model, as it is not computed by the Atmosphere-Ocean General Circulation Model (AOGCM) that provides inputs to the statistical climate emulator.

The model calculates the spatial distribution of a wide range of climatic and climate-related parameters over full interglacial cycles in response to the forcings. The emulator can then be used to derive climate data for particular areas smaller than the grid scale of the AOGCM through downscaling of the global climate modelling results using physical-statistical downscaling based on gridded instrumental records. Downscaling is planned for both Forsmark in Sweden and Olkiluoto in Finland. There will also be further work undertaken to validate results and explore emulator sensitivity.

In discussion it was noted that many organisations still use the output of the BIOCLIM project and it may be useful to undertake a comparison of BIOCLIM output on global climate with that from this more recent work programme. The spatial resolution of the climate simulations in BIOCLIM is much coarser than for this emulator which has a resolution of between 100 and 200 km in northern Europe. The emulator is a statistical programme that is available freely online. Its availability should be mentioned in the enhanced BIOMASS methodology.

2.7 PROPOSED TEXT ON EXAMPLE USE OF A COLD ANALOGUE BASED ON SKB EXPERIENCE

SKB has used Greenland as a cold-climate analogue and some appendix text, developed for inclusion in the enhanced methodology, was summarised by Tobias Lindborg (SKB). It is not necessary to consider an entire site when thinking of analogues; rather, thought should be given to the different types of analogues that can be usefully applied.

In the case of the Swedish Forsmark site, which is subject to a temperate climate and post-glacial land uplift at present, it has been necessary to consider how the site would respond to climate change in the future. Analogue areas were therefore considered with the ‘Two Boat Lake’ catchment in Greenland being selected as a cold climate analogue. This site is subject to permafrost conditions and has been studied in detail to understand conceptual differences around processes affected by different climate conditions and what this means for dose modelling (i.e. those processes that may affect radionuclide transport). The site data derived from studies have been used to develop conceptual models for the site. Hydrological models have also been developed to build further understanding of the system function at different times (e.g. seasonal effects). The detailed site studies have allowed good understanding of sources and sinks in the landscape and element behaviour in the system to be developed.

The studies that have been undertaken and the outputs from those studies provide a useful example of how long-term landscape narratives can be developed that strengthen conceptual understanding in support of model development.

2.8 PROPOSED GUIDANCE ON CLIMATE AND LANDSCAPE MODELLING IN THE LONG AND SHORT TERM

Mike Thorne (BIOPROTA TST) summarised proposed high-level guidance on climate and landscape modelling in both the long-term and short-term. A flow chart and supportive text have already been included in the Interim report (Figure 3-1 in SKB R-18-02) that are intended to support decisions around whether climate and landscape change are to be explicitly represented in assessments and, if so, whether changes are to be represented continuously or sequentially. Whilst biosphere change largely occurs continuously, such changes do not necessarily need to be presented as explicit continuous processes in assessment models. Before adopting a non-sequential representation of biosphere change, careful consideration needs to be given to whether anything of importance happens during transitional phases that would affect the next state.

Several new flow charts have been developed that link back to the work done by MODARIA I WG6 and text is being developed around these as input to the BIOMASS enhancement. As guidance develops around this topic, it may be appropriate to point to sources of information that can be drawn upon, such as the Greenland analogue site.

Climate evolution is not just related to landscape change, however, it also affects other important features that need to be considered in assessments, such as increased precipitation etc. The suggestion was made that flow charts (or other means of presenting information) be produced that show the flow of information on climate change into different aspects of the biosphere assessment methodology.

2.9 SHARING EXPERTISE GAINED BY DEVELOPING CHERPAC AND CSA-DRL CODES TO SUPPORT BIOSPHERE MODELLING

Sohan Chouhan (CNL) gave an overview of work being undertaken at CNL in relation to biosphere modelling with a view to supporting the activities of WG6. CNL has applied the CHERPAC (Chalk River Environmental Research Pathways Analysis Code) and CSA-DRL codes to support biosphere modelling for long-term safety assessments of high-level waste disposal facilities. A variety of models are available that can be applied to different scenarios:

- ADDAM (atmospheric dispersion model) can be used for any radionuclide and can be applied to ground contamination and could, therefore, be applicable to waste disposal scenarios once radionuclides are in the surface environment.

- CHERPAC is a food chain model that covers 25 radionuclides and can be used to predict ingestion dose to humans.
- ETMOD (Environmental Tritium Model) can be used to predict tritium in air and food products following release to atmosphere. The model can also be used to evaluate re-emission of tritium from soil as well as ingestion, inhalation and skin absorption doses for humans.
- CSA-DRL can be used to predict concentrations of radionuclides in air, water, soil, sediments and food items as well as doses to humans for routine releases to air or water. The model could also be applied to groundwater discharges to the surface environment.

A spreadsheet approach for non-human biota dose assessment has also been applied to develop generic no-effect levels and other biota dose assessment approaches have been applied within CNL, including ERICA and RESRAD-BIOTA.

The experience of the CNL biosphere modelling group could be applied to support WG6, as appropriate. Whilst most of the models within the CHERPAC code could be useful to the WG, these are based on airborne releases, but the CSA-DRL code can be used to address groundwater as a source of contamination. Additional support could be offered with regards to review of documents produced by the WG and technical input to the development of text within areas of expertise.

The diversity of models presented provided good examples of the different pathways of exposure that can be applicable and could provide the basis for exploring implications for dose assessment around the diversity of farming practices, which has not been explored to date within the BIOMASS methodology. Learning from such an exercise could support assessments under different climate assumptions and associated agricultural practices.

2.10 PROPOSED TEXT ON AN EXAMPLE OF IDENTIFYING BIOSPHERE AREAS BASED ON SKB EXPERIENCE

Proposed text on SKB experience of identifying biosphere areas was summarised by Tobias Lindborg (SKB).

Various approaches can be applied to identify biosphere areas, depending on factors such as the level of ambition, stage of assessment etc. Different terms can also be applied. Within SKB, the term ‘biosphere object’ is used. Defining biosphere objects supports the building of dose models, including physically constraining the model, but also supports further planning around site characterisation.

A repository is needed in addition to a site, but this can be hypothetical, depending on the stage of the programme. A site development narrative is also needed to understand how the site may evolve over time. All of these aspects need to be integrated within the overall safety assessment.

It is important to recognise that release points may change over time as the landscape evolves and particle tracking over time can be useful in identifying different objects of interest. These are typically lowland areas such as those occupied by lakes. Once discharge areas have been identified, watersheds can then be defined around these. Sensitivity studies can be used to investigate the implications for dose from variations in object size, which can be useful in demonstrating that the focus has been on a conservative case. It is important to recognise that, in a changing landscape, the area and volume of an object can vary over time.

2.11 QUANTIFYING BIOSPHERE DOSE OBJECT CHARACTERISTICS

Ryk Klos (Aleksandria Sciences) presented an alternative approach to quantifying biosphere dose object characteristics (e.g. delineation of objects and interpretation of their evolution over time, and identification of potential water body locations), based on work undertaken for SSM and STUK. The approach is considered compatible with Example Reference Biosphere guidance within BIOMASS (EBR2b) but takes account of improved conceptualisation abilities. The approach is centred around digital elevation models, which can be used to consider how a landscape could look in the future.

The topography of an area can be used to infer where water bodies such as lakes and streams are likely to occur in the future through a closed contour approach to identifying depression areas in the landscape into which discharges could occur. Possible watershed areas around these can then be defined according to preferential flow paths that are themselves defined by the topography. Some hypothesising around land use is required, along with the development of lakes etc. (e.g. the terrestrialisation of shallow lakes over time).

The approach can be applied across a whole landscape with a statistical distribution over the landscape then giving an 'average object' that could be a useful approach for those in earlier stages of their programmes. It provides a simple and practical approach that links with the actual environment, rather than being entirely hypothetical, and could be a useful approach for evaluating 'typical doses'. However, care needs to be taken to avoid selecting objects that are too small to support PEGs. Assumptions, e.g. that the water table follows a subdued version of the topography etc. would need to be made clear.

The approach can be further supported by other models that consider the types of soils that could form in different areas and the types of vegetation that those soils could support. Such an approach has been taken by Posiva in their 2012 assessment.

The approach described is focussed on natural discharge scenarios and not wells. Furthermore, not all sites would be appropriate for such a contour-based approach (e.g. where a plateau is chosen for a disposal site). In such instances it would be the sustainability of an aquifer that would be key to evaluating dose, rather than the overall area for recharge.

Text around this approach will be developed for inclusion in an appendix to the methodology.

2.12 WORKING SESSION ON THE ROLE OF FEPS, THE BIOMASS FEP LIST AND ASSOCIATED GUIDANCE

FEP lists are tools to support assessments. Generic FEPs that might be relevant in assessments can be used to support model development. Alternatively, models can be developed and then audited against the FEP lists to ensure no important processes etc. have been overlooked. The approach can help build confidence with target audiences, demonstrating that models are comprehensive. Stakeholders can also add FEPs, which helps with stakeholder engagement. Transparency is also ensured through the process of documenting the inclusion or exclusion (with justification) of FEPs. However, there is a tendency to move away from the use of FEP lists once a site has been selected and characterisation work undertaken. The lists can, nonetheless, still be a useful means of auditing models.

The BIOMASS methodology included a generic FEP list and the same could be included in the enhanced methodology. However, the NEA also has a generic FEP list that encompasses the biosphere and is currently being updated. The intention is for the new NEA FEP list to be available online. It was therefore proposed that the revised NEA FEP list be referenced in the enhanced methodology with participants reviewing the current NEA list and suggesting any improvements/changes that should be made at a generic level. Should the decision be made to include generic lists within the enhanced methodology, thought should be given to the organisation of the lists so that they more closely fit within the overall method.

Interaction matrices are a related topic. These are essentially conceptual models. They can be developed around FEPs or based on site understanding and then checked against generic FEP lists. Interaction matrices can be useful at all stages of assessments, from generic through to site-specific and this would be good to illustrate in the enhanced methodology. There are various examples that can be drawn upon, including an example from Posiva, published in their 2012-07 report. Some text will therefore be developed around the role of FEPs and interaction matrices at different stages of assessments for the enhanced methodology, with examples provided.

Stakeholder engagement is another important topic that is not currently covered in any detail in BIOMASS. The use of FEP lists and interaction matrices can be important tools to support stakeholder engagement, aiding communication and understanding. Some guidance around what can be done in terms of stakeholder engagement may be beneficial in the enhanced methodology[j], particularly identifying possible advantages and disadvantages in alternative approaches, based on lessons learned. Overall, consideration could be given to experience in undertaking assessments and the development of lessons learned that may be helpful to those starting out in their disposal programmes. Participants are therefore encouraged to consider, in hindsight, what it would have been good to know prior to starting out on different stages and aspects of assessment programmes. This could form a discussion topic for the next TM with any text developed as a result being based around provision of examples, rather than recommendations.

In addition to discussion around stakeholder engagement, it may be useful to introduce text around timeframes. Whilst BIOMASS is focussed on long-term post-closure assessments, biosphere assessments are also required for the operational phase. Furthermore, human intrusion scenarios often assume current biosphere conditions. Some discussion and explanation around these different aspects could be useful. For example, the potential need for more detailed descriptions of the biosphere to support operational phase assessments as compared with more stylised representations of the biosphere for the long-term post-closure phase. Timeframe relating to disposal phases may therefore be a useful aspect to include. FANC has recently undertaken FEP screening for different timeframes with justification of what has been screened in/out and this may provide a useful example, potentially being presented during the next TM.

2.13 KNOWLEDGE QUALITY ASSESSMENT RELATING TO BIOSPHERE ASSESSMENT

Ari Ikonen (EnviroCase) provided an updated overview of knowledge quality assessment (KQA) approaches, which are essentially a collection of tools for quality assurance of assessments, covering both qualitative and quantitative aspects. KQA can be used to demonstrate appropriate levels of knowledge and fitness for purpose as well as identifying further research and development needs and their priorities. A key question for assessments is whether there is sufficient confidence to allow

[j] A TERRITORIES workshop on this topic was held in 2017 that may provide useful information (see https://territories.eu/workshops). The SITEX and SITEX II projects also relate to stakeholder engagement in the decision making process for deep geological radioactive waste disposal (see http://sitexproject.eu/index_1.html and http://sitexproject.eu/index_2.html#deliverables). The NEA has also been active in the area of stakeholder engagement and safety case communication.

decisions on next steps to be made and KQA can help address this question, evaluating the level of confidence around different aspects of assessments, such as:

- problem formulation;
- model formulation and implementation;
- main assumptions;
- data sources and uncertainties;
- consistency and comprehensiveness; and
- meaning of assumptions, uncertainties and limitations.

Various tools can be employed within a KQA framework, including FEP analyses and interaction matrices, descriptions of qualitative and quantitative conceptual models and their scientific basis, and accounts of how conceptual models are implemented within mathematical models. Pedigree scoring can also be applied, which provides an evaluation of the strength of process understanding and of the quality of data. It can be useful to plot pedigree scores against the output from model/data sensitivity studies to identify 'what matters' (e.g. where models are sensitive to a parameter for which there is low confidence as to its empirical quality) and to present information in a transparent way. Uncertainty matrices can also be useful tools for identify where there are issues in assessments.

It may not be feasible nor necessary to check all assumptions made within assessments, but key assumptions should be evaluated to ensure that they and the overall output make sense. Consistency across models, where appropriate, should also be evaluated to avoid the introduction of unwanted inconsistencies. Consistency between different assessment groups should also be maintained where appropriate (e.g. in the boundary conditions used in operational phase assessments and environmental impact assessments).

In moving forward in the development of guidance on KQA, and similar kinds of methodologies, such as 'weight of evidence' should be captured.

2.14 WORKING SESSION ON UPDATING THE BIOMASS DATA PROTOCOL

A key message in the original BIOMASS methodology was the need to focus effort on parameters that matter for assessments and a data protocol was provided to support the gathering of data required by assessment models. This protocol links into KQA and uncertainty analysis as well as probabilistic assessment approaches. The messages within the data protocol should not be lost within the enhanced methodology.

One of the challenges in assessments is how to integrate data obtained through site characterisation. The amount of data generated through site characterisation can be vast and overwhelming and yet decisions must be made on the selection of appropriate data for input to assessment models.

Figure 4-1 in SKB R-18-02 is the original BIOMASS data protocol figure. Currently the figure is quite focussed on dose assessment and this could be made less specific so that it fits more broadly in the context of biosphere assessment. Consideration is also required as to the best location for this protocol within the overall enhanced methodology and in terms of the overall assessment process. It was suggested that some narrative could be added on experience in identifying and specifying key data for assessments, which could help those in earlier stages of assessments, helping focus on what are the key relevant areas and avoiding pitfalls such as looking too widely in an effort to encompass everything. Clear links with KQA should be made. It was agreed that the TST would develop ideas around a revised version of Figure 4-1 for discussion during the next TM. This should include thoughts around linking exposure and landscape models and their data requirements.

Within the overall enhanced methodology, care should be taken to avoid suggesting that data are prescribed. For example, ICRP dose coefficients are often suggested as being prescribed data, but they are not intended as such; alternative data can be justified as demonstrated recently with regard to ingestion of C-14 in drinking water. It is important that assessments be informed by the site (where a site is identified) and for the site to inform on the appropriate data. However, where no site has been identified, generic data will be required, and it would be useful within the enhanced methodology to signpost to possible generic data sources, such as TRS-472, as well as providing guidance around what is likely to matter for assessments that can help guide site characterisation as programmes develop. Guidance could also be developed around the use of generic data. For example, within TRS-472, 'all soil data' can be used when at a very generic stage of assessments, but when more information is known concerning possible soil types, then the underlying databases can be useful to derive more relevant parameters[k].

2.15 PROPOSED TEXT ON A SITE-GENERIC ESTUARINE, COASTAL AND MARINE BIOSPHERE EXAMPLE

Russell Walke (BIOPROTA TST) presented a possible example for a site-generic estuarine, coastal and marine biosphere, based on work undertaken for RWM. No site has been selected in the UK for a geological disposal facility, but a generic assessment has been undertaken to demonstrate feasibility and acceptability, and to maintain capability. Previous studies focussed on the terrestrial system on the assumption that exposures would be higher due to greater dilution encountered in estuarine and marine systems. However, there was no specific reference was available to back up this assumption. Furthermore, hosting communities may be coastal-based and an ability to assess exposures from estuarine and coastal habits is therefore required. A generic model extension to the RWM terrestrial exposure model was developed, focussed on the types of estuarine and coastal systems found around England and Wales. The model focuses on exposure of people, but environmental concentrations can be extracted as input for biota dose assessments. Due to the site-specific complexity of estuarine systems and the generic nature of the study, a pragmatic snapshot in time approach has been taken.

There are three components to the model: an estuary with either direct discharge to the estuary or input via river transport; coastal foreshore discharge with the foreshore being rocky and/or sandy in nature; and direct discharge to the marine environment. Each of these components can be connected. Interaction matrices were used to help conceptualise how radionuclides could move throughout each of these systems, which provides a useful example of how interaction matrices can be employed in a site-generic context.

Since the model was developed in a site-generic context, generic UK data compilations were used to parameterise the model. The use of these generic data compilations also helps to ensure consistency

[k] The significance of variability of measurements within sites and between sites is also discussed in the context of soil properties in Sheppard, S. C. (2011). Robust Prediction of Kd from Soil Properties for Environmental Assessment, Human and Ecological Risk Assessment: An International Journal, 17: 1, 263 — 279

with other assessment programmes (e.g. through the use of consistent habit data with that used in LLWR assessments etc.).

The example helps illustrate how generic models can be developed and used to support further stages in assessment programmes, for example, by identifying data needs through sensitivity analysis studies. Such studies have recently been completed with important parameters being identified that will be fed through to characterisation programmes as they develop.

Reports on the development and application of the model will be distributed. Certain aspects will be selected to illustrate considerations of relevance for inclusion in the enhanced methodology, such as use of interaction matrices and the choice of PEGs.

2.16 A NEAR-SURFACE DISPOSAL EXAMPLE WITHIN AN ERODING COASTAL CONTEXT

Alex Proverbio (LLWR) introduced an example of how the BIOMASS methodology can be applied to a case where the repository itself can be considered to enter the biosphere as a result of disruption through coastal erosion.

The UK Low Level Waste Repository (LLWR) is situated in a coastal location in north-west England. LLW Repository Ltd is required to submit an updated Environmental Safety Case (ESC) by 2021. As part of the ESC work, a number of tasks are ongoing to refine the understanding of the system required to produce an updated ESC in 2021. One of such tasks is to revise climate-change projections, including sea level rise for the timescales of interest for the LLWR. The definition of appropriate PEGs is also under review, along with the radiological assessment model.

The near-field, geosphere and biosphere are so closely coupled during the disruption of the LLWR due to coastal erosion that an integrated assessment model of proportionate complexity is required to assess this pathway. Whilst the radiological assessment model is to be reviewed and updated, the overall view on the biosphere is likely to remain unchanged. Certain aspects, such as the rate of sea-level rise that could affect assumptions around when the disposal system could be disrupted may, however, be revised. Other aspects being considered in the review include uncertainties on how FEPs have been considered and understanding of the evolution of the estuary. Such review will ensure that the representation of system evolution in the assessment is consistent with current understanding.

Waste acceptance criteria (WAC) were defined to enable safe disposals at LLWR considering several requirements. Among the requirements is to assure that the impacts that waste could have on humans and the environment during the disruption of the LLWR through coastal erosion will be acceptable. Additionally, WAC prevent the unacceptable presence of discrete items on the foreshore when the site is disrupted by coastal erosion.

The timeline for the ongoing work programme is such that it is unlikely that reports from the work will be available as input to the 2020 BIOMASS update. It may, however, be possible to provide some information in support of the methodology enhancement that illustrate aspects of the ESC, such as the use of climate information to inform site understanding etc.

2.17 DISPOSAL FACILITIES IN ARID LANDSCAPES

Mike Thorne (BIOPROTA TST) described a possible arid climate example, based around the El Cabril site in Spain. Other arid sites that could provide additional warm/arid climate examples with different foci include a Pakistan example, where the site is affected by monsoons, and Yucca Mountain that has changing fluvial pathways.

El Cabril is the facility used for the disposal of all low- and intermediate-level radioactive wastes in Spain. The facility is located on the top of a hill and cap stability needs to be considered. Exposure pathways of interest include cap erosion, bathtubbing (overtopping), gas release across the cap and groundwater transport. For groundwater transport, the height of the groundwater table with respect to climate events needs to be considered.

Arid sites tend to be event-driven, being subject to extreme discrete rainfall events and the use of long-term climate parameter averages may not be appropriate when evaluating long-term safety. Extreme climate events can have implications for water transport pathways as water is forced through the environment. Safety cases for facilities in such environments should, therefore, take account of evidence of past events to inform on what should be considered in terms of possible scenarios and test cases. Thought is needed as to whether models can capture extreme events appropriately and whether there would be merit in developing some guidance around this topic.

For any facility, irrespective of the climatic setting, the design should consider the profile of the land and potential events that could disrupt a facility. In arid environments that have the potential for erosion from extreme events, designing the facility to fit within the existing land profile may help mitigate against erosion risks. The waste to be disposed of should also be considered. For example, if organic materials or corrodible metals are to be disposed, then anoxic disposal conditions should be avoided to mitigate against the risks of bulk methane and hydrogen gas generation.

Pulse releases have not been considered to any great extent to date and may merit further discussion. Assessment models tend to require equilibrium data, which would not be appropriate for a pulse release. A pulse release scenario may therefore merit explicit consideration within the enhanced methodology[l], although pulse releases should be linked with optimisation of the facility design to mitigate risks. Further discussion is therefore required as to whether the development of a pulse release example would be useful.

2.18 MODEL APPLICATION AND EVALUATION OF RESULTS

Model application and evaluation of results is a topic that is only briefly covered in the original BIOMASS methodology and requires further development. Guidance around this topic and reporting should include recognition that there will be further iterations of assessments. The communication of results in the context of the overall safety assessment should also be captured.

2.19 WORKING SESSION TO DISCUSS TECHNICAL APPENDICES

To ensure the BIOMASS methodology remains concise, supporting information will be provided in a series of technical appendices. Several suggestions have been made for topics, including:

- climate and landscape change, a draft of which has been prepared;
- long-term sea-level change (prepared);
- data protocol and uncertainty analysis, including KQA (see below);
- site characterisation (see below);

[l] There is a Nordic regulators' guidance book that discusses appropriate averaging over pulse releases in the context of deep repositories in crystalline bedrock that may be useful in this regard.

- PEGs questionnaire output; and
- biota dose assessment.

References will be added where appropriate to further information sources throughout the methodology and supporting appendices. These should be drawn from a wide range of programmes that represent generic through to site-specific examples. The examples given within the enhanced methodology should be concise, illustrating specific aspects of the methodology.

2.19.1 Annex on Uncertainties

Ari Ikonen (EnviroCase) provided an introduction to uncertainties in assessments (sources, types and what can be done to address uncertainties) as an input to discussions around this topic and the development of a proposed annex.

The IAEA view, in terms of safety standards, is that assessments should be fit-for-purpose, with an appropriate level of detail and conservatism, and with significant deficiencies in scientific understanding, data or analysis being identified. Furthermore, models should be validated and quality assured.

There are several sources of uncertainties and different types, but there are approaches that can help address uncertainties, such as the use of probabilistic assessments. For example, a probabilistic assessment around future lake development has been undertaken on behalf of Posiva that has taken account of uncertainties in topography and land uplift and what this means for future lake development and characteristics. Uncertainty matrices and KQA (see section 2.13) are other approaches that can be taken to help identify and manage uncertainties. It is important to acknowledge that it is not feasible to remove all uncertainties, but where uncertainties are known, these should be documented. Where uncertainties are documented, they can then be managed. This may involve, for example, describing and/or quantifying the uncertainties in the context of their safety relevance, or reducing the uncertainties through further research and development etc.

An annex on uncertainty analysis was proposed previously that would describe sources and types of uncertainty (including bias) and what can be done, including KQA. Whilst the annex would provide technical detail, the topic of uncertainty is relevant to all aspects of the methodology and this needs to be appropriately captured within the main presentation of the overall approach. A means of illustrating the process of gaining knowledge from site characterisation to inform model development through to the point where adequate knowledge has been gained (i.e. when more information does not affect assessment models) would be useful; acknowledging that sufficient information has been gained is a form of uncertainty management. This also links to the need for iterative assessments throughout the process of making a safety case with each iteration informing on what matters and what further supporting knowledge is required to support decision making. One issue that should be addressed in this regard is the need to compare uncertain numbers from assessment models with fixed regulatory criteria, particularly when there are different numbers generated through the different assessment iterations. Building confidence in assessments and demonstrating safety should therefore be touched upon. Good examples to illustrate confidence building would include the LLWR non-hazardous substances assessment and the Andra safety case where scenarios have been built with safety margins.

It should be made clear in the methodology that different safety cases will require different assessment studies, driven by the assessment context. This should be mentioned early in the methodology since it provides justification for why the method cannot be more prescriptive. It would also be useful to include some discussion around where and when probabilistic methods can be useful (including the need to consider correlations when undertaking probabilistic assessments) and how also deterministic methods (e.g. alternative calculation case specifications or 'what if' cases) may be effectively used.

2.19.2 Annex on Use of Site Data

The development of an annex on site characterisation was proposed that would provide discussion around site characterisation and data needs and provide some guidance around the use of data derived from site-characterisation programmes, along with some discussion around uncertainties. The annex should be concise, but illustrative, referencing out to sources of further information. One particularly useful input to the development of the annex will be an SKB report (currently being translated into English) that sets out the basis for their planning and implementing of a site-characterisation programme that provides a nice illustration of the prioritisation process applied to inform the characterisation programme. Information within Posiva report 2012-01 on a construction-phase monitoring programme that was informed, in part, by a FEP analysis, will also be drawn from, along with reports that detail the number of samples collected over time and space in monitoring programmes. Care should be taken when developing the annex to ensure that the assessment context is included in relation to data needs, as these data needs will be very much defined by the assessment context.

The annex should aim to capture how monitoring programmes evolve alongside assessment programmes from informing site understanding through to evaluating construction impacts. It is not intended that the annex should recommend how to undertake site-characterisation programmes, but rather give examples that could provide useful context for others, or on identification of suitable analogues where site measurements are not possible. Consideration should also be given to other examples (outwith SKB and Posiva experience) to avoid too much focus on these more developed programmes (examples should illustrate different stages of assessments from generic to site-specific). Inclusion of near-surface facility examples would be good to ensure the enhanced methodology is not too focussed on geological disposal facilities.

2.20 WALK THROUGH OF THE METHODOLOGY

In the final session of the workshop, Russell Walke (BIOPROTA TST) facilitated a walk-through of the methodology to assign responsibilities, but also to identify further revisions. Responsibilities and actions are captured in Section 3. Particular revision areas are detailed below.

- A glossary of terms will be developed for inclusion in the enhanced report and participants are invited to highlight specific terms from the interim report that should be included. IAEA terminology will be used, where appropriate. Throughout, the term 'contaminant(s)' is to be used in place of radionuclide(s). A definition of the biosphere is currently included within the methodology and this needs to be reviewed by all participants.

- The working title of BIOMASS-2020 is currently being used for the enhanced methodology, but more thought and discussion is required within the working group and with the IAEA on what the full title will be.

- A key discussion area for the next TM will be the figures depicting the steps in the methodology (discussed in Section 2.3). Participants are requested to review the different figures and provide feedback/suggestions, with the TST revising each figure in the light of feedback received. The figures should be useful guides in developing the report with steps in the figures being linked to specific report sections (potentially hyperlinked in electronic versions). It should be made explicit in the report that the work flow illustration is for guidance only and is in no way intended to be prescriptive. It may also be worth noting that while assessments undertaken since 2000 have drawn on the original methodology, none have precisely followed each step; they have each adapted the approach suit their context. This is also to be expected of any updated guidance.

- The third paragraph in Section 2 should be moved to the beginning of the section to emphasise the point being made.
- It is important to recognise that there are different levels of complexity in assessments. This is mentioned in Section 2.2, but the section should be reviewed to ensure the point is suitably emphasised. Examples from elsewhere in the document could be referenced to illustrate the point. Terms such as 'relatively simple' and 'relatively complex' were suggested.
- Within the section on assessment philosophy, it is to be made clear that assessments are not intended to provide a single number for comparison against some regulatory criterion. Rather, it is the totality of the information that should be used in the context of evaluating safety.
- Boxes will be used for supplementary information throughout the description of the methodology with each being limited to one page in length. If further information is required, this may be captured in annexes.
- The term geosphere-biosphere interface (GBI) has been controversial for some time and an alternative terminology may be useful for the enhanced methodology. The term GBI can refer to different assessment teams or to the interesting region between the geosphere and the surface environment where there are strong gradients in conditions (e.g. redox, mixing with meteoric water etc.). In terms of the latter, several suggestions were made for alternative terms, including 'area of interest' or 'source term to the biosphere', which would be more relevant for near-surface disposal facilities.
- The suggestion was made to swap sections 3.1.1 and 3.1.2 so that an overall picture of environmental changes is gained prior to identifying objects of importance.
- More balance is needed regarding climate considerations. Currently much of the focus is on ice-sheet formation and its influence on the landscape, but warming can be equally important. Additional consideration of repositories in arid contexts could redress the balance.
- Where participant work programmes are identified that could serve as useful examples for aspects of the methodology, those participants will be contacted to request they produce text. Decisions will be made by all working group participants on which examples to then include in the final report.
- Section 5 on model application and evaluation of results requires further development. This should focus on confidence building around the assessment approach adopted. The BIOPROTA TST will develop this section for discussion during the next TM.
- More scientific references are required to support the methodology and participants are requested to provide relevant references, including ones in the publication process.
- Work on uncertainties and KQA will be incorporated into the methodology (in addition to the appendix that is to be developed).

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. Where programmes are used as examples to support the methodology, contact will be made with the relevant organisations to ensure the material is approved for use (and participants will be asked initially to develop example material).

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 during workshops are not missed. The TST will then contact participants of the work programme to request that areas are further developed where they are known to have the skills and experience to take certain aspects forward. There may also be merit in organising sub-group meetings to discuss and further develop specific aspects of the methodology.

3.1 ACTIONS AND RESPONSIBILITIES

The following specific actions were agreed and timescales for action are illustrated. It should be noted however that, at the time of the workshop, BIOPROTA TST funding had not been confirmed and the scope and timescales for completion of tasks may therefore be subject to change as 2018 project funding is finalised.

	Action	Person(s) responsible	Timescale
1	Review of figures 1-1 and 1-2 and provision of feedback and suggestions for improvements	All	End September
2	Develop alternative versions of Figure 1-1 (potentially removing the distinction between biosphere and geosphere) for discussion.	TST	October TM
3	Revision of Figure 1-2 (including further development of circular workflow version) in line with suggestions given in Section 2.3.	BIOPROTA TST / Ulrik Kautsky	October TM
4	PEGs questionnaire to be distributed to BIOPROTA members	Lise Griffault / Graham Smith (with support from BIOPROTA TST)	August
5	Provision of PEG questionnaire responses	All	Mid-September
6	Development of biota population assessment guidance	BIOPROTA TST	October TM
7	Contour-based approach to object characterisation	Ryk Klos	End 2018
8	Distribution of the NEA FEP list	Russell Walke	August
9	Review of NEA FEP list and suggest revisions at a generic level. Collation and submission of suggestions during the next TM.	All	October TM
10	Development of draft guidance on the role of FEP lists and interaction matrices with examples.	BIOPROTA TST	October TM
11	Consider lessons learned in terms of what would have been good to know at the start of assessment programmes.	All	October TM
12	Distribution/presentation of FEP screening for different timescales	Maryna Surkova to seek permission to distribute/present	October TM

13	Develop ideas/suggestions for a revised data protocol figure (Figure 4-1 in R-18-02) and sign-post generic data sources	BIOPROTA TST	October TM
14	Distribute reports on the RWM generic estuarine, coastal and marine model	Russell Walke	August
15	Development of example text to illustrate aspects of the generic estuarine, coastal and marine model, such as use of interaction matrices to support model development, sensitivity analyses to identify key data requirements and choice of PEGs for generic assessments	BIOPROTA TST	October TM
16	Develop text around representing extreme events within safety assessments (linked to arid climates)	BIOPROTA TST/ Danyl Perez-Sanchez (Ciemat)	October TM
17	Include consideration of pulse releases and equilibrium modelling approaches	BIOPROTA TST	October TM
18	Development of site characterisation annex	Ari Ikonen	October TM
19	Model application and evaluation of results – development of guidance	BIOPROTA TST	October TM
20	Development of data protocol, uncertainty and KQA technical appendix	Rodolfo Avila, Ari Ikonen, Mike Thorne & Ryk Klos	
21	Check whether the IAEA Safety Glossary can / should be used.	Joanne Brown	Complete
22	Review biosphere definition	All	October TM
23	Highlight specific terms that need definition in a glossary	All	October TM
24	Suggestions for relevant scientific publications to be referenced	All	October TM
25	Comments and suggestions for revisions of any aspect of the methodology are to be emailed to the BIOPROTA TST (Russell Walke) and WG6 leader (Tobias Lindborg) to ensure that points are not missed.	All	Ongoing

The next joint BIOPROTA workshop / WG6 technical meeting will be held in Vienna from 22-25 October 2018.

APPENDIX A. MEETING PARTICIPANTS

The workshop was attended by the following participants.

Participant	Organisation
Alex Proverbio	LLWR, UK
Alexander Diener	BfS, Germany
Andreas Poller	Nagra, Switzerland
Ari Ikonen	EnviroCase, Finland
Ayeoung Kim	KINS, Korea
Dawn Montgomery	Clemson University, USA
Donghee Lee	KAERI, Korea
Gerard Bruno	IAEA, Austria
Graham Smith	GMS Abingdon, UK (BIOPROTA TST)
Jari Turunen	TUT, Finland
Joanne Brown	Environmental Radioactivity Consultancy, UK
Karen Smith	RadEcol Consulting, UK (BIOPROTA TST)
Lauri Parviainen	Posiva, Finland
Lise Griffault	Andra, France
Maria Norden	SSM, Sweden
Maryna Surkova	FANC, Belgium
Mike Thorne	Mike Thorne and Associates, UK (BIOPROTA TST)
Natalie Lord	University of Bristol, UK
Neale Hunt	NWMO, Canada
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