BIOPROTA

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

Continuing Issues in Biosphere Assessments for Radioactive Waste Management

Report of an International Workshop

28 – 29 May 2015, Madrid, Spain

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PREFACE

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

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

This report describes presentations and discussions held during an international workshop on Continuing Issues in Biosphere Assessments for Radioactive Waste Management held 28 – 29 May 2015 hosted by CIEMAT in Madrid.

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

Version History

Version 1.0: Draft workshop report prepared by Karen Smith (RadEcol Consulting Ltd) and Graham Smith (GMS Abingdon Ltd) based on participant contributions, distributed to participants for comment on 21 July 2015.

Version 2.0. Final workshop report prepared on the basis of comments received from workshop participants on the version 1.0 report, distributed to workshop participants and sponsors on 26 August 2015.

Executive Summary

Since its formation in 2002, the BIOPROTA forum has worked to address uncertainties in long-term biosphere assessments of impacts arising from contaminant releases associated with radioactive waste management, identified through consultation with member organisations. Whilst the activities undertaken have gone a long way to addressing many important matters, critical issues continue to arise as disposal projects and related investigations evolve. This workshop on Continuing Issues was therefore organised to provide a forum for sharing experience on approaches to address these issues, and make further progress through development of joint work programmes and activities.

Presentations and discussions took place covering three main areas.

- Scope for model validation based on time series monitoring and related data. This included data for further testing of models for C-14 long-term dose assessment; the use of data from legacy sites, such as areas affected by Mayak PA and Llyn Trawsfynydd, which was the recipient of liquid effluent discharges from the now decommissioned Trawsfynydd nuclear power station. In addition, natural analogue sites were considered, with particular reference to those subject to land-use change.

- Addressing non-radiological impacts from waste disposal alongside the radiological impacts. The results of the BIOPROTA workshop on comparison of assessment methods for radioactive and hazardous waste, hosted by NRPA earlier in the year, were taken into account.

- Review and update of the IAEA's BIOMASS 2001 "Reference Biospheres" methodology. Scope arises for this to be carried forward within BIOPROTA in cooperation with the IAEA as part of the follow-up of the current MODARIA assessment programme.

Common features of the discussions were methods for improving confidence in long-term assessments, the role of different types and styles of models, and the need for consistency in assumptions for the biosphere and elsewhere in post-disposal safety assessments.

Outline proposals were developed in each area, as reported below. The BIOPROTA Technical Secretariat and other participants agreed to consider their further development in continuing cooperative work programmes.

Financial support for the workshop was provided by ENSI, LLWR, NUMO, Posiva and SKB. The technical and financial support of participants and sponsoring organisations is gratefully acknowledged. Special thanks are due to Danyl Pérez-Sánchez for making the local arrangements and to CIEMAT for hosting the workshop.

CONTENTS

1. INTRODUCTION

Since its formation in 2002, the BIOPROTA forum has worked to address uncertainties in long-term biosphere assessments of impacts arising from contaminant releases associated with radioactive waste management, identified through consultation with member organisations. Whilst the activities undertaken have gone a long way to addressing many important matters, critical issues continue to arise as disposal projects and related investigations evolve. This workshop on Continuing Issues was therefore organised to provide a forum for sharing experience on approaches to address these issues, and make further progress through development of joint work programmes and activities.

The workshop was held in Madrid on 28-29 May 2015, hosted by CIEMAT.

1.1 OBJECTIVES AND SCOPE OF THE WORKSHOP

The objective of the workshop was to provide a forum for sharing experience on approaches to address a number of identified continuing issues in long-term biosphere assessments for radioactive waste management, including:

- Scope for model validation based on time-series monitoring data at legacy sites;
- Addressing correlations, not just between model parameters, but also in assumptions in conceptual model development, including assumptions for human behaviour;
- Design of assessments to support demonstration of optimisation and/or selection of options for disposal;
- Assessments to address waste containing NORM and other radioactive waste in the same disposal facility and the disposal of LLW/VLLW with other waste in facilities not specifically intended for radioactive waste;
- Long-term storage methods for site characterisation samples;
- The disposal of radioactive waste and non-radioactive hazardous waste and the feasibility of developing a single toxicity index that addresses the chemical and radiation hazards;
- Application of groundwater protection legislation to radioactive waste repositories; and,
- Review and update of the IAEA's BIOMASS 2001 "Reference Biospheres" methodology, to account for:
    - Experience from examples of practical application since 2001,
    - Experience of site characterisation at real sites,
    - Science developments, e.g. understanding of long-term climate change and variability,
    - Inclusion of a closer link to the remainder of the safety assessment, via the Geosphere-Biosphere Interface,
    - Consideration of a wider range of assessment endpoints: especially complementary indicators and non-human biota, and

- Updates to international recommendations and guidance from IAEA and ICRP and examples of national regulatory development.

1.2 TECHNICAL AND FINANCIAL SUPPORT

The workshop was attended by 22 participants from 10 countries, representing a range of operators, regulators, researchers and technical support organisations. Participants and their organisations are listed in Appendix A. Additional presentations were provided by interested persons that were unable to attend the workshop and were presented on their behalf by the BIOPROTA Technical Secretariat.

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1.3 REPORT STRUCTURE

Based on the degree of interest and level of discussion from participants, the report of the workshop has been structured as follows:

- Section 2 focusses on the scope for model validation using time-series monitoring and other data.
- Section 3 details discussions around addressing non-radiological impacts from waste disposal alongside radiological impacts.
- Section 4 outlines ideas for a review and update of the IAEA's BIOMASS 2001 "Reference Biospheres" methodology.

2. SCOPE FOR MODEL VALIDATION BASED ON TIME SERIES MONITORING AND OTHER DATA

2.1 PROPOSAL FOR MODEL TESTING FOR C-14

To date, the main focus of BIOPROTA activities in relation to C-14 assessment modelling has been on the terrestrial system, and specifically the transfer of C-14 from soils to different crops. Quantitative comparisons of different models have been undertaken, leading to further model development by participant organisations. Subsequent to these activities, new data have been identified that may allow for further model testing exercises to be developed. These data sources were recently the subject of discussions during a BIOPROTA workshop on long-term dose assessments for C-14 (reported in Smith & Smith (Eds), 2015), specifically in relation to developing scenarios to allow C-14 assessment models to be further tested. The data sets of particular interest are outlined below.

- IRSN have undertaken field monitoring studies over a 3 year period at a grassland site in the vicinity of the Cape de la Hague reprocessing plant resulting in time-series data of C-14 in air, soils and grass at the monitoring site with supporting meteorological data. The data have been used by IRSN to develop a process-based model and by IRSN and SSM in undertaking a model-data, model-model inter-comparison exercise.

- In addition to the IRSN monitoring data, further data is now also available as a result of a series of laboratory and field experiments undertaken by the University of Nottingham on behalf of RWM. The objective of the experiments was to further understanding of the behaviour of methane in the soil system, oxidation to carbon dioxide and uptake into plants. The experiments involved injecting C-13 at the base of the soil rooting zone (approx. 45 cm deep) and measuring the diffusion of methane up the soil column and formation of carbon dioxide. Release from the soil, in both vegetated and unvegetated, homogenous and natural soils was also measured. Laboratory soil column experiments were also undertaken using C-14. A model has been developed on the basis of the experimental results on behalf of RWM.

- Further data may also be available from a series of publications relating to the AECL Duke Swamp site at which a number of studies have been undertaken to investigate the migration of C-14 from a waste management area and uptake into plants and animals. No publications have been identified to suggest that modelling work has been undertaken to date in relation to the Duke Swamp data although a PhD project has recently been concluded in which some statistical modelling was undertaken of C-14 behaviour in the area between the waste management area and the swamp.

With the la Hague data set having previously been used as the basis for a model testing exercise, a full scenario description is already available along with good data on meteorological conditions and soil and plant measurement data. Some additional data have also been identified that provide time-series information for C-14 in air and pasture over the period 2009 to 2014. These latter data are publicly available and IRSN is happy to make their monitoring data set available to others interested in taking part in a model testing exercise.

The RWM data set has recently been made available to SSM, via Quintessa, and is likely to be available more widely for a model testing exercise, if requested. No scenario description currently exists for this data set, but could be developed from the reported descriptions of individual field and laboratory column experiments. In applying the RWM data, consideration would need to be given as to which of the field

and laboratory experiments should be used for calibrating models and which should then be used in validation activities.

The Duke Swamp site presents a greater challenge. The site, being a natural area, is not constrained and the research that has been undertaken has resulted in multiple independent data sets that are not necessarily for the same areas or for the same measurement endpoints and are varied in terms of the time at which the research was undertaken. Development of a scenario description for model testing would therefore be more complex than for the previous data sets. The data for Duke Swamp nonetheless provides an interesting possibility to investigate C-14 behaviour in a non-agricultural system and the data could be collated and be used as the basis for developing conceptual models. Furthermore, and as noted during the C-14 workshop (see Smith & Smith (Eds), 2015), the swamp data may provide a useful opportunity to apply a recently developed methodology for evaluating processes in the geosphere-biosphere sub-system.

Whilst there is interest in comparing models against data from real sites, a link with safety assessments should be maintained and consideration given to how best to represent short-term processes in long-term assessments. The testing of models in their capability to reproduce short-term processes is however considered beneficial. Once confidence has been gained in the ability to represent such processes, then information can be abstracted and used to justifiably simplify the representation within long-term models. There is a need however to develop an understanding of the system that is being modelled. In past inter-comparison exercises, not enough effort is considered to have been placed on this aspect and, as such, the output from the comparisons may not be as beneficial as it could have been. It is not a trivial task to develop a well-scoped scenario and consultation with potential sponsors at an early stage is therefore considered beneficial. The IRSN data set was recognised as being useful in allowing models to be tested with regard to their ability to represent short-term processes, but with the source term being an atmospheric discharge, the applicability to long-term modelling will be limited. The Duke Swamp data set would be very interesting due to the timescales over which the contamination has occurred and the transport of C-14 in groundwater. However, whether or not there are sufficient data to allow a robust scenario to be developed is not yet known and whether there are sufficient data to allow a structured time-series of data to be established also requires further investigation. There is however a significant data set on tritium for the site that, in combination with data on C-14 and specific hydrological investigations (such as measurements of water levels in boreholes), may provide a sufficient understanding of the hydrology at the site. Furthermore, with some biota data being available, it may be possible to evaluate transport in the food chain in addition to transport through and between environmental media over time. Two projects could therefore be envisaged with one focussing on C-14 transport (including losses by volatilisation) and one focussing on site hydrology, which would be very interesting in terms of the geosphere-biosphere sub-system. Information on the source term, for example the chemical form of C-14, would be required however to constrain the scenario.

It was agreed that Laura Limer (Quintessa) would develop short proposals on what could be done with each of the data sets for discussion and consideration within the BIOPROTA community.

2.2 POSSIBILITIES FOR USING LEGACY SITE INFORMATION

Graham Smith presented information from a presentation by Malgorzata Sneve (Norwegian Radiation Protection Authority, NRPA) that was given during a workshop on ‘International Workshop on “Radioecology and Assessment Research in Support of Regulatory Supervision of Protection of the Environment and Human Health at Legacy Sites” that was held in Barcelona on 7 September 2014. The information related to areas affected by historic releases from the Mayak PA facility in Chelyabinsk, in the Southern Urals; a legacy site that could possibly be used for model testing, and for testing the geosphere-biosphere sub-system (GBS) methodology developed within BIOPROTA.

The NRPA has a long-term regulatory co-operation agreement with the Federal Medical and Biological Agency of Russia (FMBA)[a]. Within this program it is highlighted that regulatory decisions must be supported by good scientific understanding. Three projects have recently been completed to improve understanding of behaviour of environmental radioactivity and related dose assessments in areas affected by historic releases from the Mayak PA nuclear facility.

The main radioactive source terms to the environment from Mayak PA have included planned discharges, which were very large during the 1950s and 60s, both to air and surface water bodies. In addition, a chemical explosion in 1957 resulted in a substantial contaminated plume extending tens of kilometres to the northeast of the site. Furthermore, in 1967, Lake Karachai, a water body receiving radioactive liquid effluent, dried out, leading to dispersion of contaminated dust from the lake bed into the wider environment. The area has therefore been monitored due to resultant health protection concerns and, as such, the ecosystem has been well characterised in terms of surface land and water bodies, near-surface hydrology and long-term monitoring results for Cs and Sr deposition are available.

Of the three projects noted above, one focussed on the health status of fish within the Techa River, which received very substantial releases from the Mayak PA facility during the early years of operations. Results of the Comet assay and other analyses have indicated health effects in fish taken from the most contaminated stretch of the river in comparison with fish taken from a similar nearby river that was not affected by radioactive releases. However, a causal link to radiation has not yet been proven. Another study, in this case in cooperation directly with Mayak PA and Rosatom, focussed on the processes leading to reduction of contamination in, and remediation of, lakes and reservoirs in the region. Apart from studying the scope for remediation by natural processes and human interventions, prognostic modelling has also been undertaken, but this did not allow for further contamination arising from further releases into the lakes from contaminated groundwater. A third project has examined the dynamics of body burdens and internal exposure from long-lived radionuclides of residents of Ozyorsk, a town situated near Mayak PA[b].

If the data for the site are of interest as the basis for testing models for aquatic systems, then an approach could be made to the NRPA and FMBA to request access to the data for this purpose. It may also be possible to develop a more complex test scenario involving movement of, in this case, Sr-90 infiltration following deposition from the atmosphere, and sub-horizontal transport in groundwater to surface-water bodies. Such an analysis could be locally relevant, support understanding of relevant processes, and be used to test to GBS methodology[c]

In addition to the Mayak PA site, there may also be other legacy sites for which suitable monitoring data are available and for which timescales of contamination could provide interesting opportunities to test the longer-term aspects of assessment models. For example, there are a number of lakes for which

[a] For a recent description of remediation work in Northwest Russia, focussed on Andreeva Bay, see Sneve et al (2015). Radiation safety during remediation of the SevRAO facilities: 10 years of regulatory experience. J. Radiol. Prot. 35 (2015) 571–596 doi:10.1088/0952-4746/35/3/571.

[b] For a recent description of remediation work, see Suslova et al (In review). Dynamics of body burdens and internal exposure doses from long-lived radio-nuclides in the residents of Ozyorsk situated near the Mayak PA. Submitted to JRP.

[c] BIOPROTA (2014). An Exploration of Approaches to Representing the Geosphere-Biosphere Interface in Assessment Models. Report prepared under the BIOPROTA international programme. Report prepared under the BIOPROTA international programme.

measurement data for a range of elements are likely to be available such as at Llyn Trawsfynydd in Wales for which water, sediment and fish time-series monitoring data may be accessible as a result of monitoring of discharges from the Trawsfynydd nuclear power plant whilst it was operational. Similarly data may be available from lakes in Sweden, linked to uranium contamination and for which land evolution is an interesting feature.

It was further noted that there is a natural analogue uranium outcrop peat bog site in Scotland (Broubster, Caithness) that has been studied over several decades[d]. Data from those earlier studies could be taken into account, but also allowing consideration in terms of changing land use, given that part of the site has since developed to a forested area.

With a range of data being available for the Trawsfynydd site it was suggested that a test case could be undertaken whereby the source term is back calculated from current monitoring data. If there is sufficient interest in the Llyn Trawsfynydd data, the possibility of developing a test case can be investigated by Adrian Punt (RadEcol) who has previously undertaken work in this area on behalf of the Environment Agency.

[d] Read D (1990). Geochemical modelling of the Broubster natural analogue site, Caithness, Scotland. Work carried out under cost-sharing Contract No FI1W/0073-UK with the European Atomic Energy Community in the framework of its third R&D programme on 'Management and storage of radioactive waste' (1985-89), Part A, Task 4 'Geological disposal studies' EUR 12342 En. Available at: http://bookshop.europa.eu/en/geochemical-modelling-of-the-broubster-natural-analogue-site-caithness-scotland-pbCDNA12342/

D. Read and P. Hooker (1989). "The speciation of uranium and thorium at the Broubster natural analogue site, Caithness, Scotland." Mat. Res. Soc. Symp. Series, Sci Basis Nucl. Waste Manag. **XII**, 763-770.

3. ADDRESSING NON-RADIOLOGICAL IMPACTS FROM WASTE DISPOSAL ALONGSIDE THE RADIOLOGICAL IMPACTS

A workshop on 'Comparison of Safety and Environmental Impact Assessments for Disposal of Radioactive Waste and Hazardous Waste' was held in Asker, Norway in February 2015. The workshop was driven by recognition that a coherent and consistent approach is required for chemicals and radiation, particularly in relation to the disposal of mixed wastes.

A number of significant issues were identified during the workshop that could be further addressed, including:

- Feasibility of developing a single toxicity index that addresses the chemical and radiation hazards.
- Criteria for human health and environmental protection from the non-radiological hazards: e.g. what is the equivalent quantity to {x mSv/a} or mGy/hour for Hg, and what would you need to consider in order to determine the value?
- Methods for criteria for determining limits on package content of hazardous chemicals in radioactive waste packages.
- Application of groundwater protection legislation to radioactive waste repositories, e.g. the EU Groundwater Daughter Directive[e]
- Assessments to address waste containing NORM and other radioactive waste in the same disposal facility.
- Disposal of LLW/VLLW with other waste in facilities not specifically intended for radioactive waste.

A particular question of interest that arose from the workshop was whether it would be possible to develop a single toxicity index that would work for both radionuclides and non-radioactive chemicals. Were this possible, the threat levels from radioactive and chemical wastes could be compared on the same scale. Having such an index would provide multiple benefits, not least of which would be that it could be applied to determine which factor of a waste stream should be the focus of more detailed risk assessments, in terms of mitigating risks and to help in decision making. Such an index would also be of benefit in communication with stakeholders and the public on issues around radioactive waste management and could assist industry in the development of waste acceptance criteria. Inconsistencies in the regulation of chemical and radiation hazards have been noted previously. For example, Public Health England undertook a study on common risks in relation to the disposal of very low level radioactive waste, including uranium, to Clifton Marsh in 2006. This study was in support of a public consultation on disposals, however no further work has been undertaken to date on the common risk approach, but this continues to be of interest.

The key limiting factor in the development of a common toxicity index is likely to be the limited availability of toxicity data for chemicals since each chemical has to be evaluated individually due to the varied modes of action. For those chemicals for which toxicity data are available, the lowest effective

[e] For further discussion, see http://waterissues.eu/2013/11/20/groundwater-pollution-revision-of-the-daughter-directive-annexes/

concentration causing a degree of effect or the maximum no effect concentration could serve as the basis for deriving a common index. Data on 'no effects' or equivalent endpoints are not available for many chemicals however and, where these are available, they are not always on a comparable basis. Unlike the field of ecotoxicology, where different chemical species are evaluated according to different protection endpoints, radioecology, as applied to radiation protection, has the same assessment endpoints for all radionuclides, expressed in terms of effective dose for humans or absorbed dose rate for other biota. Consideration of individual chemical forms (or classes of chemical) and speciation are likely to be required for both radiological and chemical risk assessment.

A further complicating factor is that chemicals standards can provide different levels of protection as well as protection of different things, such as human health or aspects of environmental protection such as fisheries viability or sediment quality. Different levels of risk that people are willing to accept can also vary according to the type of contamination. For example, a higher level of risk may be accepted for some contaminants, especially where it is considered not cost effective to address the issue, but only very low levels of risk are accepted if there is particular concern with respect to a given contaminant.

It was discussed that it would be more appropriate to consider the index as a guide as to the level of significance or threat to the environment, rather than an indicator of risk. Risk assessment implies deeper analysis, for example, the probability of exposure in addition to level of exposure.

With the limitations recognised above, it was suggested that a starting point could be to compile the different approaches to evaluating compliance with standards and ways in which safety is demonstrated, based on experience in various countries and internationally. It would not be feasible to look at all chemicals and therefore the focus should be on those elements that have already been identified as potentially relevant in terms of chemical toxicity for radioactive waste disposal. Such studies have been undertaken by a number of organisations, including RWM and NWMO.

It is commonplace with regard to mixed wastes to consider the hazard associated with radioactivity initially and to then consider the chemical hazards in order to inform on the disposal mechanism. Comparing the hazards posed by radioactive and non-radioactive materials would be interesting for sites such as NORM disposal sites, uranium mines and associated liabilities such as tailings ponds and waste heaps, and hazardous landfill sites that are also permitted for the disposal of VLLW. Such sites exist throughout the world and the subject would have wide application as well as being interesting. It was suggested that spending on waste management can be very inconsistent: for example, arrangements for low-level radioactive waste disposal can be very expensive compared with hazardous waste disposal and yet the hazards are often the reverse.

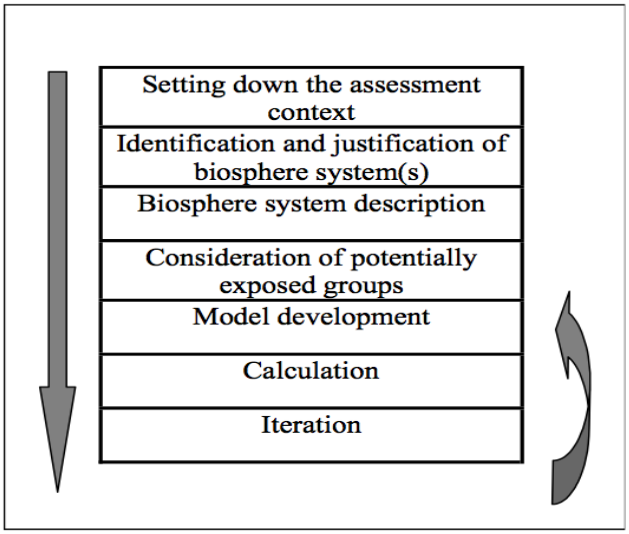
A report could be prepared on the problems faced in developing a single toxicity index, with a focus on science rather than risk perception. Such a report could detail the implications for health and the environment of just complying with available standards. For example, the 1 mSv/y dose limit relates mainly to the risk of an individual getting cancer whereas the WHO/ATSDR standard for uranium in drinking water implies no hazard as it is based on a small fraction of the NOEC (no observable effect concentration). The uncertainties associated with effects can be treated very differently between radioactive and hazardous materials with safety factors being applied for chemicals, but not for radionuclides. In some instances, use of a safety factor with NOEC data can give rise to protection criteria that are at levels below natural background. A report of this nature could potentially provide the basis for considering implications for the disposal of radioactive and hazardous wastes in terms of the Groundwater Daughter Directive and demonstration of compliance. A discussion paper on whether or not it is feasible to create a single toxicity index could then be prepared.

In addition to the above, interest was noted in investigating what is being done in various countries and internationally with regard to assessment of impacts of chemicals in radioactive waste, criteria employed and approaches to addressing data gaps. In this regard, the basis for the standards is not the key issue; rather, identifying data to allow compliance to be demonstrated should be the focus, along with information on how chemical speciation (e.g. Cr(III) versus Cr(VI)) and physical form (e.g. crystalline or amorphous) are or are not addressed. The point of compliance is also an interest area with regard to where this should be set in demonstrating compliance with the Groundwater Daughter Directive. Some work is already underway to investigate this issue in the UK.

4. REVIEW AND UPDATE OF THE IAEA'S BIOMASS 2001 "REFERENCE BIOSPHERES" METHODOLOGY.

The IAEA BIOMASS-6 report on reference biospheres for solid radioactive waste disposal was published in 2003[f]. The report sets out a structured approach for determining what should be included (or at least considered) in an assessment and provides representative examples. Included within the report is a methodology for developing new reference biospheres for situations where the examples provided are not directly applicable. With the focus of such assessments being on future biosphere conditions, the approach is intended as a basis for deriving reference biospheres for use as measuring instruments rather than a prediction of future conditions and exposures. The steps within the structured approach are shown in Figure 4-1.

Figure 4-1. Steps in the IAEA Reference Biospheres approach.



The reference biospheres methodology has been widely applied in radioactive waste disposal assessments, giving rise to new knowledge and developments in approach. For example, initially, one model tended to be applied to assess all radionuclides, but the need to model radionuclides with complex environmental behaviour individually has been recognised to ensure that key processes and their interactions can be addressed at a suitable level of detail. There have also been substantial developments in relation to how climate is addressed in long-term assessments, e.g. the EU BIOCLIM project[g], results of WG3 of the IAEA EMRAS II programme[h] and on-going work in the IAEA MODARIA

[f] 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.

[g] Agence Nationale Pour la Gestion des Déchets Radioactifs, Bioclim (2004). Development and Application of a Methodology for Taking Climate-Driven into Account in Performance Assessments, Work Package 4: Biosphere System Description, Deliverable D10-12, EC contract no. FIKW-CT-2000-00024, ANDRA.

[h] IAEA (2012). Environmental Change in Post-closure Safety Assessment of Solid Radioactive Waste Repositories, Report of Working Group 3 of the Environmental Modelling for RAdiation Safety (EMRAS II) Programme, Final draft from participants presented to the IAEA, October 2012, International Atomic Energy Agency, Vienna, Austria.

programme. Another important development is the application of approaches to allow radiation effects on the environment to be evaluated. There have also been technical developments in models for radionuclide migration and accumulation in different parts of the environment, such as representing the sorption behaviour of radionuclides through the 'intelligent Kd' approach. There have also been significant updates since 2003 in international recommendations on standards for, and methods for assessment of, post-disposal radiological impacts, both from IAEA and the ICRP. Apart from these developments, there have been substantial examples of the application of the reference biospheres methodology and other work, including site investigation and characterisation methods and interpretation, in site-generic and site-specific circumstances, which provide useful experience. As such, it is considered timely for the reference biospheres approach to be reviewed and updated to take account of this new knowledge and experience.

Following discussion, the initial approach suggested for developing the methodology was to form topic-specific task groups and such an approach may be a good means of ensuring focus on key areas in updating the methodology. For example, a task group could be formed to look specifically at special radionuclides. The aim would be to retain the basic methodological steps shown in Figure 4.1, i.e. not be to change the overall approach, but rather to manage information and experience, particularly with regard to developments in addressing environmental change, which was not deeply considered in IAEA-BIOMASS-6, computational resources and experience in addressing special radionuclides such as C-14. Since the publication of the original methodology, there has been significant development of more flexible simulation systems.

With model approaches having developed since the initial methodology was published, it was suggested there may be merit in considering alternative approaches to presenting conceptual models. The previous approach was to use interaction matrices, but there can be the potential for these to become very complicated to take account of the various interactions and processes. As such, a table format, combined with an interaction matrix may prove useful, as was used in the BIOPROTA GBS project.

One question that would be good to address in an update of the methodology is how to upscale from data at a small scale into larger-scale models, i.e. how to translate information from process-based models to more empirical, parameter-based models, and how heterogeneity should or could be addressed. The complexity of models is largely dependent upon the scale of assessment. On a small scale, models can be very complex in order to represent detailed and important processes. However, as the assessment moves to a larger scale (i.e. considering a whole landscape), simplifications are required. Advice on how to embed one scale of assessment into another is required. Correlations between critical processes and parameters should also be identified and advice provided on how to select appropriate assessment parameters. Consideration should also be given as to whether continuous evolution of a system through time is required or whether a stepwise approach is appropriate, based, in part, on recent work conducted through WG6 of the IAEA MODARIA programme.

A project looking at 4-D statistical landscape modelling and stylised approaches was presented on behalf of Tampere University of Technology in Finland. A research group at the university has been looking into the use of both complex and simple modelling approaches and a PhD project has recently completed[i]. A statistical landscape model has been applied to obtain a topographical representation of the landscape, looking at various features such as the probabilities of sizes of future lakes with land

[i] Pohjola, J. 2014.Probabilistic Modeling of Landscape Development and Surface Water Body Formation. Tampere University of Technology, Pori. Dissertation. http://urn.fi/URN:ISBN:978-952-15-3420-1.

uplift as a function of time. More recently, a public-funded research programme began in 2015 that is focussed on the stylisation of models through systematic testing, aided by the statistical modelling. This ongoing work, funded by the Finnish national nuclear waste research programme, aims to expand competence in the use and representation of reference biospheres. Within the project, it is intended that a library of ecosystem-specific reference biospheres, of varying degrees of detail, with input datasets will be developed and consideration given as to how to connect ecosystems in a developing landscape. 'Rules' on what can be done with respect to systematic FEP analysis, scenario development and sensitivity and uncertainty analysis will also be documented. The starting point for the work is the Posiva landscape model, with consideration given as to whether simplifications are appropriate and justifiable. The project has only just begun and it would be timely therefore to engage with the group to synchronise activities with regard to the BIOMASS methodology update and to compare results as the work develops.

In addition to the points noted above, it was noted that experience from license submissions to date and the corresponding regulatory review of safety cases would be very relevant. The intention would not be to necessarily change steps in the assessment method, but rather to expand the detail on those steps, based on more recent experience, for example that arising from the IAEA EMRAS II and MODARIA programmes mentioned above. However, an additional endpoint relating to non-radioactive impacts of radioactive waste disposal could be incorporated. Human intrusion aspects could also be included.

Further consideration on the best approach to taking forward this programme of work is required. Once further developed, a plan could be developed and distributed both to BIOPROTA member organisations and the IAEA, which has expressed interest in a joint project in this area, forming part of the follow-up to the current MODARIA programme. The plan should identify particular technical work programmes (e.g. within BIOPROTA and the IAEA) that could inform the update process and could include detail on envisaged task group topics and resource application suggestions. Essential aspects could be identified based on the experience of those that are further ahead in their waste disposal programmes to avoid over-complicating the overall programme. In addition to reviewing and updating the methodology, it was considered that new examples of application should also be presented, with a focus of examples on specific issues to feedback as to whether the methodology is fit for purpose in addressing those issues. Particular interest exists as to the general relevance of application of a well-release scenario, how to address environmental change, and how to ensure a coherent link to the rest of the safety assessment, though, for example, consideration of the GBS. Alternative conceptual models of a single biosphere system may provide a further basis for developing confidence in long-term dose assessments.

Finally, it was noted that the IAEA Safety Assessment Methodologies for Near Surface Disposal Facilities[j] (ISAM) post-date the IAEA-BIOMASS-6 methodology report and it may therefore be appropriate to take this into account during any review and update of BIOMASS.

[j] http://www-pub.iaea.org/books/IAEABooks/6971/Safety-Assessment-Methodologies-for-Near-Surface-Disposal-Facilities

APPENDIX A. LIST OF PARTICIPANTS

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