The IAEA’s Programme on
MOdelling and DAta for Radiological Impact Assessments
(MODARIA)

Uncertainties and Variability
Working Group 6
Common framework for addressing environmental change in long term safety assessments of radioactive waste disposal facilities

MINUTES
of the Second WG6 Meeting held SKB Headquarters, Stockholm, Sweden
28–29 May 2013

Objectives
The objectives of the meeting were to present and discuss the work done so far in Working Group 6 (WG6), to review the WG6 Work Plan and to further define the programme of activities within each subgroup. In addition, the opportunity was taken to present information and context to new participants.

Introductions and Background
Participants were welcomed to the meeting and to SKB by the WG6 Leader, Tobias Lindborg. Each person introduced themselves and explained their interest in attending. A List of Participants is given below. Participants were reminded of the objectives of WG6, as being to develop the understanding of how the biosphere may develop from present to the far future, by:

— Defining the key processes which drive environmental change (mainly climate change), and describing how a relevant future may develop on a global scale. The results can be used to describe the future environments, which we call ‘reference futures’ and ‘future variants’. These are not predictions but relevant examples that provide valuable input for solving specific questions in a safety assessment.
— Developing a methodology (conceptual framework) that is valid on a global scale, and considering how that can be downscaled to provide information that is needed for site-specific assessments.
— Applying the conceptual framework to a number of case studies (sites), that will illustrate the evolution of site characteristics and the implications for the dose assessment models, including the justification of abstraction into simplified assessment-level models. This may address: (a) changes in the potentially affected environment prior to any assumed radionuclide release to the biosphere; and (b) changes occurring after or while releases are assumed to occur, including possible transient effects that may be relevant to resulting potential exposures.

Version 1.0 of the Work Plan, developed from the first meeting of WG6 was designed to achieve these objectives through the setting up of three subgroups:

— SG1: Global Climate and Climate Related Processes (led by SKB)
— SG2: Applying Narratives for Relevant Futures (Description of Site Development) to Specific Sites (led by HMGU)
— SG3: Analysing Process Understanding and Confidence (led by SSM)

Plenary Presentations
Presentations were made to provide further background and update of related project progress, as follows:

— Common framework for addressing environmental change in long-term safety assessments of radioactive waste disposal facilities (T Lindborg)
— Previous collaborative work on inclusion of environmental change in repository assessments (G Smith)
— Global aspects of environmental modelling (G Proehl)
— Current knowledge on future climate evolution (J Brandefelt)
— Climate considerations in long-term safety assessments - examples from Sweden (J-O Näslund)
— Use of climate simulations in Posiva's safety case, including climate modelling work at the Finnish Meteorological Institute (A Ikonen and A Lehtinen)
— Beyond BIOCLIM: Activities in BIOPROTA and the Forward RWMD Programme (M Thorne)
— Reference Biosphere Models for El Cabril following the BIOCLIM Narrative (C Staudt)
— Addressing climate change in assessments for L/ILW in Spain (D Perez-Sanchez)

It addition, Mr Lindborg noted the recent publication of a special issue of AMBIO, which includes substantial information relevant to WG6, e.g. papers on: Climate Considerations in Long-Term Safety Assessments for Nuclear Waste Repositories; Landscape Development During a Glacial Cycle: Modeling Ecosystems from the Past into the Future, and Humans and Ecosystems Over the Coming Millennia: Overview of a Biosphere Assessment of Radioactive Waste Disposal in Sweden.

Subgroup Discussion

Participants divided into the subgroups, to discuss the application of the new information and to further develop the separate subgroup activities. See Annexes A, B and C.

Plenary Discussions and Conclusions

Subgroup plans were presented and reviewed during plenary sessions, and these are included in Annexes A, B and C and define the continuing programme of activities for WG6 at least until the next meeting in November 2013, at which time an updated overall WG6 Work Plan may have been developed. The progress towards a WG6 overall report was also discussed and the following outline developed:

Outline of WG6 Project Report

1. Background, Objectives and Scope
2. Approach to Carrying Out the Study
3. Global Climate and Climate Related Processes (SG1)
4. Applying Narratives for Relevant Futures to Specific Sites (SG2)
5. Analyzing Process, Understanding and Confidence (SG3)
6. Conclusions and Recommendations

The links to other MODARIA WGs continue to be recognized alongside the BIOPROTA programme of activities (www.bioprota.org), particularly the project on the geosphere-biosphere subsystem.

Next Meeting

The next meeting of WG6 will be held at IAEA headquarters in Vienna 11–15 November 2013 as part of the Second MODARIA Technical Meeting.
### Attending

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<thead>
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<th>IAEA Scientific Secretary</th>
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### Participants

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Annex A: SG1 Discussion and Plan: Global Climate and Climate Related Processes

The following steps had been initially identified in version 1 of the WG6 Work Plan.

1. Describe the selection of global model type by identifying:
   — The project specific objectives;
   - Key questions to be addressed (generic and specific, inclusion of human impact on climate change, timeframe for assessment and other matters);
   - Global climate development models;
   - Global sea-level development models;
   - Permafrost/regional aspects;
   - What is already available, both as models and results of their application?

2. Illustrate the use of them and their down-scaling, but this has to be project specific [e.g. site characteristics, assessment context], and in so-doing, identify gaps in model capabilities.

3. Identify climate-related issues you need to describe: for example erosion, precipitation, permafrost, temperature, ice cover. This gives information on what the narrative (description of development) needs to include.

4. Give a description of the methodology for downscaling at specific sites. This includes the definition of data requirements.

5. Provide an interim summary of the methodology from 1 to 4.

6. Produce site-specific narratives, as many as needed, with descriptions of the temporal climate evolution, for example in terms of climate states (e.g. as illustrated via a “climate development chart”).

7. Discuss the relevance of different models to different project requirements, e.g. site selection, communication of a level of understanding, specific aspects of meeting technical protection objectives.

The following points arose from discussion in the May meeting.

The types of geological disposal facility that should be addressed include both near-surface and deep facilities in a range of geographical contexts. These contexts range from areas subject to glaciation to semi-arid/arid areas well beyond the limits of any Quaternary glaciations. There is a need to give consideration to the full range of potential sites worldwide for geological disposal of solid radioactive wastes. A taxonomy of the various types of facility of interest was developed characterising them by type (shallow/deep), geological context, geographical location, topographic conditions, and the range of climatic conditions that might arise in the future.

Consideration was given to the relevant outputs that are available from global climate models of various types [including Earth Models of Intermediate Complexity (EMICs) and Atmosphere-Ocean General Circulation Models (AOGCMs)]. The outputs needed to provide inputs to landscape evolution, hydrological, hydrogeological and assessment models were discussed. It was recognised that the outputs delivered by the global climate models are not always immediately applicable to the other types of model and that an intermediate step of translation will be required. It was also recognised that bridging the gap between climate model outputs and the inputs to other models may also involve the use of current observational data and the use of palaeo-indicators of past climatic and environmental conditions.

In translating between climate model outputs and the inputs required by other models, considerations of both temporal and spatial scale arise. Both EMICs and AOGCMs typically operate on coarse spatial grids, so there is the need to downscale the results to a more local scale (taking account of factors such as topography and aspect). Various approaches to downscaling exist (model-based, statistical and rule-based) and the robustness and appropriateness of these techniques need to be explored. Some EMICs are based on a set of sectors (e.g. individual ocean basins and continental land masses) rather than being based on a geographical grid, so special rule-based procedures are required to interpret outputs from such models in terms of local
climatic conditions. In terms of temporal scale, the climate models may only deliver mean values averaged over extended periods, so the results may not have adequate time resolution for use in some contexts (e.g. providing boundary conditions to process-based, spatially distributed models of surface-water catchments). Careful consideration has to be given to whether temporal downscaling is required (e.g. does it imply that an unduly complex hydrological model is being used). If it is required then the use of a technique such as a weather generator conditioned by longer-term climatic information may be required.

Typically, AOGCMs are run in snapshot mode or in transient mode for timescales of up to a few hundred years (though transient calculations over periods of up to a few thousand years have been undertaken). The boundary conditions for such runs may be either fixed atmospheric greenhouse gas concentrations or time-varying concentrations based on various emissions scenarios that make alternative assumptions concerning the size of fossil fuel reserves and the extent to which they will be utilised. Because of the long time steps typically associated with EMICs (due to the asynchronous coupling to ice-sheet models often employed), calculations covering a few hundred years are of little relevance and this time domain is better explored using AOGCMs. Beyond a few thousand years, EMIC modelling is the only approach available. There is now sufficient overlap in the modelled timescales that explorations comparing the results of AOGCMs and EMICs over periods of a few thousand years would seem to be feasible.

Palaeo-environmental data are available over the full range of timescales of interest (e.g. tree ring data going back a few thousand years and sediment core data with variable resolution covering the whole of the Quaternary offshore and about the last million years at a few locations on-shore). Continuous instrumental climate records extend back a few centuries at a limited number of sites and about 100 years at many climate stations around the world.

Taking account of this discussion, the following outline plan was developed:

— Associate a text to the defined tables describing systems (Mike Thorne end of August 2013)
— Develop a decision tree describing key questions and choices made related to climate evolution (SKB by November 2013)
— Develop a diagram describing how the global climate develops in time depending on latitude... (SKB by November 2013)
— Find and describe available datasets for analogue climates, and how to use them (Mike Thorne by November 2013)
— Develop a narrative of different model linkages from climate to landscape models (Mike Thorne and Jens Becker by November 2013)
— Develop climate assessment model flow chart (SKB by June 2014)
— Identify site-specific climate narratives and the methodology behind (e.g. Finland, Sweden, England, Spain and Canada by 2015)
— Investigate other countries/climates climate narratives (future action)
Annex B: SG2 Discussion and Plan: Applying Narratives for Relevant Futures (Description of Site Development) to Specific Sites

It was agreed that the key tasks and deliverables for SG2 should include:

1. Development of a generic methodology for interpretation of climate narratives
   a. For use in landscape and hydrology system description models
   b. For use in dose-assessment models
2. Example model application (for a and for b)
3. Full application to specific sites… e.g. C England

The work to achieve these will be to some recent dependent on the outputs from SG1. However, prior to the next meeting in November 2013, the following activities were agreed:

— Creation of analogue models and results for a range of relevant locations (Staudt):
  • e.g. El Cabril, C England, (using BIOCLIM narratives) and Forsmark, Olkiluoto, Busher, Rokkasho (other sources)
— Review of BIOCLIM and post-BIOCLIM use of the BIOCLIM approach in SG2 (Interpretation of climate narratives) (Kowe)
— Collation of Biosphere Dose Conversion Factors\(^1\) from assessments prepared for different sites around the world and consideration in the context of climate related issues, and what impact they have (Smith)
— Engage with BIOPROTA project on processes in the geosphere-biosphere subsystem (Staudt and Smith)

Based on the above, including outputs from SG1, a range of calculations will be performed to determine the significance of different climate conditions and transient effects. These will focus on key radionuclides (for example as identified in the BIOPROTA programme. Mr Staudt agreed to carry out some preliminary calculations, for well release and a sandy soil, presenting doses to adults and interim concentrations in various media to inform non-human biota dose assessments. He also agreed to include some uncertainty analysis.

\(^1\) Typically, values of Sv/y to exposed individuals due to a continuous release of 1 Bq/y from the geosphere to the biosphere.
Annex C: SG3 Discussion and Plan: Analysing Process Understanding and Sources of Confidence in the Use of Biosphere Models in Post Closure Safety Assessment with Focus on Long Term Climate Change

Introduction

The historical development of biosphere models for dose assessments has been on-going for over thirty years. Taking BIOMOVS II and BIOMASS as benchmarks, the kind of biosphere modelling carried out in the context of dose assessment during the 1980s and 1990s was fairly straightforward. A Reference Biospheres Methodology has been developed via international collaboration in the BIOMASS project (van Dorp et al., 1999; IAEA, 2003; Crossland et al., 2005) to construct stylised biospheres based on climate and landform development from the characteristics of the present biosphere, as recommended for long-term impact assessments of nuclear waste repositories. Generic modelling was therefore appropriate then and simple compartment structures with different degree of detail were the basis for assessment modelling.

Geosphere/biosphere interface (GBI) processes are considered important for estimating potential sources that could lead to dose consequences (Wörman et. al., 2004; Kirchner, 2009). However, traditionally in long-term safety assessments geosphere and biosphere simulations are treated separately as two parts. For example there is no inclusion of complex processes such as distribution of pathways across GBI and accumulation due to geochemical processes and interaction between surface waters and groundwater (e.g. Klos et al., 2011, Pérez-Sánchez et al., 2012). Ecosystem Dose Factors (EDFs) (Sv/y per Bq/y) for various environmental media are calculated based on unit radionuclide input (Bq/y) to the biosphere. The radiological consequences due to possible radionuclide release from waste repositories are evaluated by multiplying EDFs with simulated radionuclide fluxes (Bq/y) from the geosphere. The simplified dose evaluation that neglects GBI processes can lead to an underestimation of potential radiological consequences due to neglect of accumulation processes within various biosphere compartments (Wörman et al., 2004).

A more integrated approach for “landscape models” has been developed recently based on site-specific data in the Swedish waste management program (Berglund et al., 2009), which was applied in performance assessments for the first time in the SR-Can exercise (SKB, 2006). In this approach the climate evolution (glaciation cycles), land uplift and a number of connected biosphere objects, i.e. Reference Biospheres, are considered. This approach has been further developed (SKB, 2010) and applied in the post-closure safety assessment, SR-Site (SKB, 2011), in connection to the license application for construction of a geological repository for spent nuclear fuel.

It is a challenge to find a balance between complexity of models and confidence in the predicted model results for long-term radiological assessment. On the one hand, complex models with a high spatial and temporal resolution are needed to describe various features, events and processes for long-term safety assessment. On the other hand, models with thousands of input parameter values are not transparent and therefore difficult to review by authorities and explain to the public. Recommendations for radiological assessment models used for waste disposal might be given based on the balance between complexity and transparency and the balance between generic and site-specific approaches.

Objectives

The objective of the planned work in SG3 is to analyse process understanding and sources of confidence in the use of biosphere models in post-closure safety assessment with focus on long term climate change. Planned activities to fulfil the objective are:

— Comparison between the role, structure and content of biosphere models for dose assessment having different degrees of complexity (e.g. for different types of site or at different stages of repository development).

— Identification of the key processes and parameters affected by long-term climate change and of their uncertainties, and analyses of their impact on dose assessment by performing sensitivity analyses.

— Justification of selected model descriptions for certain processes by comparing with experimental data and natural analogues.

Finally, findings from this activity will be documented and recommendations will be given.
**Proposed working method**

To achieve the objectives the plan is to compare site-specific models with simpler models (e.g. the “reference biosphere” approach according to the BIOMASS project) and with medium complex biosphere models:

— A first “simple reference biosphere model” will be implemented with the “reference biosphere” approach by including the most plausible transport processes and various types of biosphere objects such as a well, agricultural land, lake and wetland.

— A second model will be implemented and analysed as an alternative medium complex biosphere model by including the most plausible transport processes and two or three combined biosphere objects as well as some elements of succession within biosphere objects.

Site specific data sets will be used as a basis for the model comparison. An example of a schematic diagram for those three different models is shown in the figure below.

![Diagram showing models](image)

**Activities for site A (Swedish site)**

A.1 Model comparison between the “complex site specific model” and the “reference biosphere model”

   a. A list of site-specific model objects and an overview of how these objects vary with time
      i. Type of ecosystems
      ii. Area of the ecosystems
      iii. Characteristics of the ecosystems
      iv. Identifying the main processes for the evolution of the ecosystems

   b. A list of reference biosphere models
      • An agricultural land, a well, a wetland, a river, a lake etc…

   c. Modeling exercises for model comparison
      i. Type of ecosystems
      ii. Area of the ecosystems
      iii. Characteristics of the ecosystems
A.2 Model comparison between the “complex site specific model” and the “medium complex model”

a. Development of a “medium complex model”
   i. Model which takes into account the main processes for ecosystem evolution identified above
   ii. Model which may take into account a couple of connected ecosystems
   iii. Uncertainties and sensitivities of all the parameters used in the model can be explored

b. Modeling exercises for model comparison

A.3 Findings, discussions and reporting

a. Comparison of the capabilities, advantages and weakness as well as costs of the above mentioned three approaches,
b. Recommendations and guidance
c. Reporting

Activities for site B (Spanish site)

The Spanish case will be applied to an specific site, the low level and intermediate level waste disposal facility, located at El Cabril province of Cordoba.

A.1 Model comparison between complex model and reference biosphere model

a. A list of site specific model objects and an overview of how these objects vary with time
   i. Type of ecosystems
   ii. Area of the ecosystems
   iii. Characteristics of the ecosystems

b. A list of reference biosphere models
   • An agricultural land, a well, a river, a dam etc…

c. Modeling exercises for model comparison
   i. Type of ecosystems
   ii. Area of the ecosystems
   iii. Characteristics of the ecosystems

A.2 Model comparison between complex model and simple assessment model

a. Development of a simple assessment model
   i. Model which takes into account the main processes for ecosystem evolution identified above
   ii. Model which may take into account a couple of connected ecosystems
   iii. Uncertainties and sensitivities of all the parameters used in the model can be explored

b. Modeling exercises for model comparison

A.3 Findings, discussions and reporting

a. Comparison of the capabilities, advantages and weakness as well as costs of the above mentioned three approaches,
b. Recommendations and guidance
c. Reporting
**Time schedule**

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<td>Work plan for SG3</td>
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<td>2013-06 to 2013-12</td>
<td>Data collection for Site A &amp; B and initial modeling results</td>
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<tr>
<td>2014-01 to 2014-12</td>
<td>Update modeling of Site A and B</td>
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<td>2015-01 to 2015-12</td>
<td>Reporting of modeling of Site A &amp; B</td>
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<tr>
<td>2016-01 to 2016-06</td>
<td>Finalizing (recommendations) reporting</td>
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At the next annual MODARIA meeting 11-15 November 2013 the plan is to present preliminary results from the modeling of Site A (Swedish site for HLW) and Site B (Spanish site for LILW). At the meeting SG3 also plan to work with mapping (and quantification) of sensitivity of processes and parameters to long-term climate change for dose modeling purposes, e.g. identify new issues.

**References**


