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Climate change and landscape development in post-closure safety assessment of solid radioactive waste disposal: Results of an initiative of the IAEA

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ABSTRACT

The International Atomic Energy Agency has coordinated an international project addressing climate change and landscape development in post-closure safety assessments of solid radioactive waste disposal. The work has been supported by results of parallel on-going research that has been published in a variety of reports and peer reviewed journal articles. The project is due to be described in detail in a forthcoming IAEA report. Noting the multi-disciplinary nature of post-closure safety assessments, here, an overview of the work is given to provide researchers in the broader fields of radioecology and radiological safety assessment with a review of the work that has been undertaken. It is hoped that such dissemination will support and promote integrated understanding and coherent treatment of climate change and landscape development within an overall assessment process.

The key activities undertaken in the project were: identification of the key processes that drive environmental change (mainly those associated with climate and climate change), and description of how a relevant future may develop on a global scale; development of a methodology for characterising environmental change that is valid on a global scale, showing how modelled global changes in climate can be downscaled to provide information that may be needed for characterising environmental change in site-specific assessments, and illustrating different aspects of the methodology in a number of case studies that show the evolution of site characteristics and the implications for the dose assessment models.

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Overall, the study has shown that quantitative climate and landscape modelling has now developed to the stage that it can be used to define an envelope of climate and landscape change scenarios at specific sites and under specific greenhouse-gas emissions assumptions that is suitable for use in quantitative post-closure performance assessments. These scenarios are not predictions of the future, but are projections based on a well-established understanding of the important processes involved and their impacts on different types of landscape. Such projections support the understanding of, and selection of, plausible ranges of scenarios for use in post-closure safety assessments.

1. Introduction

Environmental change has long been recognised as an issue requiring consideration within post-closure safety assessments (PCSAs) for solid radioactive waste disposal (Lawson and Smith, 1985; BIOCLIM, 2004; SKB, 2006; Posiva, 2006; LLWR, 2011). The International Atomic Energy Agency (IAEA) has played a significant role in coordinating and consolidating research and assessment methods in this context, notably in setting out an overall "Reference Biospheres" methodology for assessing radiation doses following radionuclide releases from radioactive waste repositories (IAEA, 2003). Subsequently, the European Commission project BIOCLIM supported better understanding of how to address climate change within PCSAs (BIOCLIM, 2004) and the IAEA provided a further international locus for analysis of how to address environmental change in PCSA. The study was carried out as part of the second phase of the IAEA programme on Environmental Modelling for RAdiation Safety (EMRAS II), was completed in 2012 and reported in IAEA (2016). That report was prepared by a wide range of participant organizations, including regulators, operators and technical support organizations from many countries. The scope of the work included the following:

- Use of data for present-day conditions at a range of different sites with different climate and other characteristics that might be considered as suitable analogues for future conditions at a specific site;
- Modelling of the important features of the soil-plant system in different climatic and other conditions;
- Use of dynamic system modelling of climate and landscape change to better understand the possible future biosphere conditions at a site, on a site-specific basis;
- A review of international recommendations and national requirements and guidance on how to address environmental change in demonstrating compliance with post-closure protection objectives.

The EMRAS II study (IAEA, 2016) showed that it is widely recognised that environmental change may affect the radiological impact arising from any eventual releases of radionuclides from radioactive waste repositories into the biosphere. This is reflected in international recommendations on post-closure safety (App 4 of IAEA, 2016; IAEA, 2012; ICRP, 2013).

In the EMRAS II study, two main approaches were identified to addressing environmental change. The first, the analogue approach, was based on the use of data for present-day conditions at a range of sites, with different climate and other characteristics, that might be considered as suitable analogues for future conditions at the specific site in question. The other main approach, which has been developed further in the MODARIA project described here, is to model explicitly the dynamic evolution of the biosphere in response to the main environmental change drivers, i.e. climate change and geomorphological changes, notably associated with sea-level changes at coastal sites, but also potentially linked to significant erosion in areas of geological uplift. This approach relies on integration of the modelling of the evolution of climate, hydrology, landform, radionuclide release from the geosphere, radionuclide migration and accumulation, and land-use. Both approaches were demonstrated to be useful in the EMRAS II study and can be considered complementary.

Detailed consideration was also given to the modelling of the soil-plant sub-system in a range of different fixed climate and other conditions. This information can be useful within the dynamic and analogue approaches, depending on the level of temporal resolution adopted. It also provides a useful starting point for assessing transient effects linked to environmental change.

It was recommended in the report of the EMRAS II study (IAEA, 2016) that future work should be directed to providing a consensus approach to addressing climate change as part of a PCSA.

Based on these recommendations, a working group (WG6) was set up within the IAEA's follow-up assessment programme, MODARIA (Modelling and Data for Radiological Impact Assessments), to develop a common framework for addressing climate change in post-closure radiological assessments of solid radioactive waste disposal in both near-surface and deep geological disposal facilities. The authors of this paper comprise the members of the working group that contributed substantially to the studies that were undertaken. The output from the working group, as described in this paper, represents the personal views of the members of the working group and cannot be interpreted as representing the views of the IAEA or its Member States.

Specifically, the overall objective of the working group was to further develop the understanding of how the biosphere may change from the present into the far future in a wide range of regional and local contexts relevant to the near-surface, intermediate depth or deep geological disposal as may be relevant to different types of solid radioactive wastes (IAEA, 2009). Thus, the emphasis was on modelling potential patterns of climate and landscape change to provide a context in which, e.g. appropriate analogue systems could be selected, and soil-plant modelling studies could be performed. To facilitate the work, a classification scheme was established for the different types of disposal facility that have been developed or proposed, so that the implications of the work for these different types of facility could be established. The timescales of relevance and the types of environmental change of most significance differ between these various types of facility.

Although this project was undertaken in the context of safety assessments of the disposal of solid radioactive wastes, the methodology that has been developed and the results that have been obtained are relevant in much wider contexts. Thus, considerations of climate and landscape change are directly relevant to evaluating the radiological impact and assessing the potential for remediation of sites with existing radioactive contamination, e.g. those that have arisen from uranium mining and milling and other legacies (Sneve and Strand, 2016). More generally, the work on modelling the long-term climatic consequences of various carbon dioxide emissions scenarios can be used to inform assessments of the long-term environmental impacts of those scenarios, i.e. beyond the next few centuries, which is the typical time horizon of climate-change impact assessments.

The results of WG6 have been outlined in a brief conference paper (Lindborg et al., 2017). The current paper provides a more detailed technical description of the methodology and illustrative examples of application. The referenced research reports and journal papers should be consulted for a comprehensive account of the science that underpins the presented methodology.

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