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Author: Roger D. Wilmot

Technical Note

2014:24

Workshop on biosphere issues

Main Review Phase

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SSM perspektiv

Bakgrund

Strålsäkerhetsmyndigheten (SSM) granskar Svensk Kärnbränslehantering AB:s (SKB) ansökningar enligt lagen (1984:3) om kärnteknisk verksamhet om uppförande, innehav och drift av ett slutförvar för använt kärnbränsle och av en inkapslingsanläggning. Som en del i granskningen ger SSM konsulter uppdrag för att inhämta information och göra expertbedömningar i avgränsade frågor. Workshopar organiseras sedan för att diskutera läget för SSM:s aktuella granskningsinsatser samt konsulternas uppdragsresultat om specifika processer, säkerhetsfunktioner och barriärer av stor vikt för SKB:s säkerhetsanalys SR-Site för kärnbränsleförvaret i Forsmark. Synpunkter samt slutsatser som resulterar från workshoparna är workshopdeltagarnas syn och inte nödvändigtvist SSM:s.

Workshopens syfte

Det övergripande syftet med denna workshop var att föra samman experter, inom området radionuklidtransport i biosfären och området dosberäkningar inklusive andra organismer än människa, för att diskutera resultaten av de detaljerade granskningar som utförts under huvudgranskningsfasen och för att identifiera eventuella ytterligare granskningsfrågor inom de aktuella områdena.

Sammanfattning av workshopen

Denna rapport beskriver den workshop om Biosfärsfrågor som SSM organiserade den 21 oktober 2013. I rapporten redovisas de frågeställningar som diskuterades och viktiga synpunkter som uppnåddes summeras. Redovisningen bör inte ses som en fullständig dokumentation av alla diskussioner under workshopen och individuella påståenden från deltagarna bör hanteras som deras uppfattning och inte som SSM:s ståndpunkter. Fyra presentationer vid seminariet sammanfattas nedan.

1. När det gäller enkla referensbiosfärsmodeller, visar en jämförelse mellan SKB:s resultat och de första resultaten från de enklare modellerna* att den metod som används i SR-Site i allmänhet inte underskattar dosfaktorer för grundvattenutsläpp till ytan. Användningen av grunda brunnar för bevattning av trädgård, som inte ingår i SKB:s modellering, är dock en exponeringsväg som kan leda till högre dosfaktorer för vissa radionuklider.
2. När det gäller hydrologi och alternativa biosfärsmodeller, stöds modelleringen av den ytnära hydrologin i SKB:s biosfärsmodeller av data från sex nutida sjöar, för vilka detaljerade hydrologiska modeller har utvecklats. För att översätta denna förståelse till radionuklidtransportmodellering för biosfären, har medelvärden av beräknade vattenflöden tagits fram och normaliserats till konstanta flödesfaktorer som har använts för det framväxande biosfärssystemet. En generell kommentar är att motiveringen är otillräcklig för den metod som används och konsekvenserna av alternativa metoder har inte undersökts.

* AEA, 2003. "Reference Biospheres" for Solid Radioactive Waste Disposal. Report of BIOMASS Theme 1 of the BIOsphere Modelling and ASSessment (BIOMASS) Programme, International Atomic Energy Agency report IAEA-BIOMASS-6.

3 När det gäller härledning av värden för sorptionskoefficienter (Kd) och koncentrationsförhållanden (CR) är slutsatsen från granskningen att även om osäkerhet i Kd-värden inte har betydande inverkan vid dosberäkning, är SKB:s härledning och motivering av dessa värden tekniskt svag och inte transparent.
4 När det gäller dos till andra organismer än människa, är de preliminära slutsatserna från granskningen att vissa delar av säkerhetsanalysen är konservativa, men det finns ett antal punkter där förtydligande information behövs, särskilt gäller det CR-värden och vilka radionuklider som ingår i beräkningarna för varje organism, vilket potentiellt kan leda till ökad uppskattad dosrat.

Workshopen kom också fram till att SSM har utvecklat tillräcklig kompetens för att förstå de aktuella biosfärsfrågorna och utvecklat modelleringskapacitet för att granska SKB:s ansökan. Denna kompetens hjälper SSM att bedöma graden av konservatism i SKB:s säkerhetsanalys och därmed att kunna försvara fattade beslut om licensansökan.

Projektinformation
Kontaktperson på SSM: Shulan Xu
Diarienummer ramavtal: SSM2011-4249
Diarienummer avrop: SSM2013-2036
Aktivitetsnummer: 3030012-4047

SSM perspective

Background

The Swedish Radiation Safety Authority (SSM) reviews the Swedish Nuclear Fuel Company's (SKB) license applications under the Act on Nuclear Activities (SFS 1984:3) for the construction and operation of a repository for spent nuclear fuel and for an encapsulation facility. As part of the review, SSM commissions consultants to carry out work in order to obtain information and provide expert opinion on specific issues. Workshops are organized for the discussion of the current status of SSM's review findings and consultants' opinions reached on particular processes, safety functions and barriers of central importance in SKB's safety assessment SR-Site for a final disposal of spent fuel at Forsmark. The viewpoints and conclusions expressed at the workshops are those of the workshop participants and do not necessarily coincide with those of SSM.

Objectives of the workshop

The objective of this workshop was to bring together experts in the field of radionuclide transport in the biosphere including non-human biota and dose assessment to discuss the findings of the detailed reviews performed during the main review phase and to identify any further biosphere review issues.

Summary of the workshop

This report describes the outcome of the workshop organized by SSM on Biosphere Issues that was held in Stockholm on the 21 October, 2013. The report summarizes the issues discussed and extracts the essential viewpoints that have been expressed. It should not be considered as a comprehensive record of all the discussions at the workshop and individual statements made by workshop participants should be regarded as opinions rather than SSM's point of view. Four presentations at the workshop are summarized below.

1 Concerning simple reference biosphere models, a comparison of SKB's approach with the initial results from simpler models* shows that the SR-Site approach generally does not underestimate dose factors for groundwater releases to the surface. The use of shallow wells for irrigation of clayey tills, which is not included in SKB's models, would however lead to higher dose factors for some radionuclides.
2 Concerning hydrology and alternative biosphere models, the representation of near-surface hydrology in SKB's biosphere models is supported by consideration of six present-day lakes, for which detailed hydrological models have been developed. In translating this understanding into the radionuclide transport models for the biosphere, the calculated water flows are averaged and normalised to constant flow factors to be used for the evolving system. Overall, there is insufficient justification of the approach used and the implications of alternatives have not been explored.

* AEA, 2003. "Reference Biospheres" for Solid Radioactive Waste Disposal. Report of BIOMASS Theme 1 of the BIOsphere Modelling and ASSessment (BIOMASS) Programme, International Atomic Energy Agency report IAEA-BIOMASS-6.

3 Concerning derivation of values of sorption coefficients (Kd) and concentration ratios (CR), overall, this part of the review concluded that, although uncertainties in Kd values may not be significant in terms of dose calculations, SKB's derivation and justification of these values is technically weak and not transparent.
4 Concerning non-human biota issues, the preliminary conclusions of the review are that some elements of the assessment are conservative but there are a number of points of clarification required, especially related to CR values and which radionuclides are included for each organism, that could potentially lead to increased dose rate estimates.

The meeting concluded that SSM had developed sufficient competence in its understanding of biosphere issues and its modelling capabilities to check SKB's application. This competence would also help SSM to establish the degree of conservatism incorporated within SKB's assessment and to thereby defend whatever decisions were reached on the licence application.

Project information
Contact person at SSM: Shulan Xu

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myndigheten
Swedish Radiation Safety Authority

Author: Roger D. Wilmot
Galson Science Ltd, Oakham, United Kingdom

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This report was commissioned by the Swedish Radiation Safety Authority (SSM). The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of SSM.

Contents

1. Introduction

The Swedish Radiation Safety Authority (SSM) is reviewing the licence application submitted in 2011 by the Swedish Nuclear Fuel and Waste Management Company (SKB) to construct, own and operate a disposal facility for Swedish spent nuclear fuel and an encapsulation plant. The review is being undertaken in a series of phases:

- Initial review phases to
  - achieve broad review of SR-Site documentation
  - identify need for complementary information
  - identify critical review issues for in-depth review in the main review phase
  - End of 2012
- Main review phase (2013 - 2014)
  - in depth review and issues resolution
- Reporting phase
  - End of 2014

Based on the comments from the initial review, twenty-five requests for clarification and complementary information about biosphere issues were sent to SKB, and four review assignments in this topic area were let for the main review phase. SKB has provided responses to some of the requests for additional information and a meeting to discuss these was held in September 2013. SKB intends to complete the response by the end of 2013.

A workshop was held on 21 October 2013 to discuss the findings of the detailed reviews and to identify any further biosphere review issues. This Technical Note summarises the presentations (Chapter 2- 5) and discussions (Chapter 6) at the workshop. The workshop agenda is included as Appendix 1.

2. Simple reference biosphere models

Russell Walke (Quintessa) reported results from a comparison between simple reference biosphere models and the models used by SKB to calculate landscape dose factors (LDFs).

The requirement for this comparison arises from the complexity of the approach used by SKB. The initial review noted that, in order to understand the degree of conservatism in this approach, the extent to which it is complete and comprehensive, and whether it is appropriate, a comparison against a simpler, non-evolving reference biosphere would be of value.

Because of the range of environments to which releases could occur, six simple biosphere models have been developed, representing the following non-evolving systems:

- Forest
- Pasture
- Arable
- Marine
- Lake
- Mire

Temperate conditions were assumed for all of the models, with sorption coefficients, diffusivities, concentration ratios and transfer factors taken from SR-Site. Specific data for clayey tills, which are suitable for long-term agricultural use, were used in addition to the data amalgamated over different media that were used in SR-Site. For the simplified dose calculations, a set of habits and occupancies was defined for each system independently of the carbon balance model and full occupancies used by SKB. Dose coefficients used in the simple models explicitly account for short-lived radionuclides – the treatment of these in SR-Site is not clear.

The representation of near-surface hydrology in SKB's biosphere models is supported by consideration of six present-day lakes, for which detailed hydrological models have been developed. In translating this understanding into the radionuclide transport models for the biosphere, the calculated water flows are averaged and normalised in such a way that there is no water balance. In addition, some of the water flows are ignored in the assessment model, including downward flow and lateral exchanges. In contrast, the flow models used in the simple biosphere models include exchanges and modify the flows from the SR-Site analysis in order to balance.

Initial results were available for the simple reference biosphere models, which showed that many of the systems modelled did not approach equilibrium for some radionuclides, even after 20,000 yr simulations. This has implications for the applicability of the dose factor approach used by SKB.

A comparison of SKB's approach with the initial results from simpler models shows that the SR-Site approach generally does not underestimate dose factors for groundwater releases to the surface. The use of shallow wells for irrigation of clayey tills, which is not included in SKB's models, would however lead to higher dose factors for some radionuclides.

Overall, the review of SKB's assessment modelling and comparison with simple reference biosphere models concludes that there is limited confidence in SKB's complex approach. This is due to some questionable modelling assumptions that are not fully explored, and because the documentation is difficult to follow.

3. Hydrology and alternative biosphere models

In addition to proposing a comparison of SKB's approach with simple biosphere models, the initial review highlighted a number of specific issues with SKB's assumptions underlying the calculation and use of LDFs. Results from a review of SKB's interpretation of near-surface hydrology, and the development of an alternative interpretation, were presented by ***Richard Kłos*** (Aleksandria Sciences) and ***Anders Wörman*** (KTH).

A review of SKB's assumptions regarding hydrology is important because hydrology is the main driver of radionuclide transport. However, for the calculation of LDFs, SKB uses an "average object", based on the hydrology of lakes, that does not have the same hydrology as objects in the landscape model that have the highest LDFs. It is also unclear whether the omission of diffusive releases to lakes from SKB's model is significant. The use of a constant normalising factor means that the "average object" would be valid only for a snapshot of the evolving system. How this relates to assumptions about evolving object areas is not well defined.

The review concluded that there is information available for each object in the evolving system from MIKE-SHE and it is unclear why this has been discarded. Overall, there is insufficient justification of the approach used and the implications of alternatives have not been explored.

Some of the alternatives will be examined using an independent biosphere model developed in order to present an alternative interpretation of the hydrology. This will include two or three biosphere objects and take account of the most plausible transport processes. It will also account for elements of succession within biosphere objects. This model is currently under development and comparisons with SKB's model will be made in due course.

4. Derivation of K_d and CR values

The initial review of the licence application noted concerns over the derivation and applicability of parameter values used to represent sorption of radionuclides and concentration ratios between radionuclides in water or soil and the food chain. ***George Shaw*** (School of Biosciences, University of Nottingham) reported a review of SKB's use of site-specific data-sets, and an on-going review to assess the consistency of SKB's data sets was reported by ***Nick Beresford*** (Centre for Ecology & Hydrology) and ***Patrick Boyer*** (IRSN).

SKB has noted that the literature values for concentration ratios (CR) and sorption coefficients (K_d) often vary by several orders of magnitude and that values used in assessments are therefore most appropriately derived from representative site-specific data. This site-specific approach has previously been recommended and supported by SSM.

SKB suggests that quite a large set of site-specific data has been obtained at Forsmark and Laxemar and used as the basis for deriving CR and K_d values, but also notes that there are limited data for inorganic deposits and suspended matter. On this basis, a review was undertaken of the reliability of the SR-Site measurements and the traceability of the site-specific K_ds. Measurement data were obtained through a request for data from the Sicada database relating to measured concentrations of Se, I, Nb and Ra in soils, sediment, porewaters, filtered waters, vegetation and mushroom fruiting bodies.

Examining the Sicada data for "true sample pairs", from which ratio values such as K_ds can be obtained, showed that site-specific data are very limited for some radionuclides. SKB has used literature data to supplement these measurements but these may be derived from very different environments (e.g., organic terrestrial K_ds supplemented with aquatic K_ds).

Overall, this part of the review concluded that, although uncertainties in K_d values may not be significant in terms of dose calculations, SKB's derivation and justification of these values is technically weak and not transparent.

For each element, SKB considers four K_d values; a single value for the lower regolith in all compartments, a single value for the middle and upper regolith in all compartments, and individual values for suspended particle matter (SPM) in the lake and sea compartments. In all layers and more particularly in lower and mid regoliths, higher K_d values increase residence times, which may lead to a decrease in the flux to the biosphere or reduce the impact of exposure pathways linked to water. Impacts associated with sediments will however be greater with higher K_ds and values cannot therefore be shown to be conservative.

The review of SKB's data was undertaken by means of a comparison with data published elsewhere (predominantly IAEA handbooks) and a comparison between the values for different layers and compartments. This comparison uses both the single, "best estimate" values reported by SKB and geometric standard deviation values that have reportedly been used for sensitivity studies but not used in the derivation of LDFs.

For both organic and inorganic deposits, the best estimate values reported by SKB are greater than or equal to values in IAEA datasets (one exception is selenium in inorganic deposits). For both marine and limnic SPM, the SKB values are less regularly distributed, with both higher and lower values than in the reference datasets.

A consideration of the processes and factors involved would suggest that K_ds in the middle and upper regolith would be between one and ten times the values for SPM. The ratios determined for SKB's data are reasonably consistent with this range for the limnic system, with the exception of neptunium and plutonium, and much more variable for the marine system. The presence of organic matter in the upper and middle regolith would be expected to result in higher K_ds than for the lower regolith and the ratios determined for SKB's data generally show this relationship.

The review of concentration ratios was reported as being underway and final conclusions had not yet been drawn.

5. Non-human biota

There is a requirement in SSM's regulations for an assessment of the potential consequences of radioactive waste disposal on non-human biota. In the licence application, SKB reported an assessment performed using the ERICA Integrated Approach and ERICA Tool. An on-going review assignment to assess whether this approach has been applied appropriately was reported by ***Nick Beresford*** (Centre for Ecology & Hydrology). The review also considered whether alternative, credible parameter values could lead to significantly different conclusions.

The ERICA Integrated Approach is a three tier approach that allows for different levels of detail in the assessment. SKB used Tiers 2 and 3 as these allow for the addition of radionuclides and organisms to the default set.

SKB has considered all of the radionuclides included within the SR-Site safety assessment, with the exception of Ac-227, Pa-231 and Pd-107, citing the absence of available data from the site or the literature with respect to biological uptake. However, the ERICA methodology provides guidance on how to select appropriate values when radionuclide data are missing and there are values for these elements in both IAEA and other SKB reports.

In terms of ecosystems, SKB has assumed that wetlands are equivalent to the ERICA terrestrial ecosystem. The review notes that the assumptions made about soil moisture contents are unclear (although likely conservative) and that wetland animals may use both terrestrial and aquatic ecosystems, although not all wetland organisms were considered in both ecosystems. SKB has also assumed that the marine environment at Forsmark is equivalent to the ERICA marine ecosystem as this is "probably adequate also for brackish water". However, the work cited in support of this assumption relates to estuaries with relatively high salinities.

SKB has assessed the ERICA reference organisms that are most likely to be seen at the site. A justification for omitting some organisms is provided but freshwater amphibian and freshwater benthic fish are omitted without justification. Given the uncertainties of long-term predictions, it was questioned as to whether any reference organisms should be omitted.

Concentration ratios between the organisms and the environment are important parameters in the assessment of non-human biota. The values that SKB has used in the assessment, for example for elements added to the ERICA default list, are not clearly documented. SKB's justification of how the values have been derived is often unclear.

The preliminary conclusions of the review are that some elements of the assessment are conservative but there are a number of points of clarification required, especially related to CR values and which radionuclides are included for each organism, that could potentially lead to increased dose rate estimates.

6. Discussion

Following the presentations and discussion of the key findings summarized above, there was a general discussion of how SKB had treated biosphere issues in the licence application and the overall conclusions that could be drawn from the review.

The reviews to date have considered biosphere issues independently of their significance in terms of overall safety. Uncertainties in scenario probabilities are likely to have more effect on calculated impacts than LDFs. An in-depth review remains important for judging SKB's overall approach and application of quality assurance, but for judging the robustness of the disposal system, there is a case for concentrating the review on key radionuclides and the factors that control calculated doses.

The meeting concluded that SSM had developed sufficient competence in its understanding of biosphere issues and its modelling capabilities to check SKB's application. This competence would also help SSM to establish the degree of conservatism incorporated within SKB's assessment and to thereby defend whatever decisions were reached on the licence application.

SSM recognises that there is no guidance regarding how the requirement to consider non-human biota should be met. The conclusions of the review will inform a decision on the adequacy of SKB's approach in SR-Site, and will also help SSM to develop more specific guidance for future use. An example would be guidance on how the areas over which radionuclides might be discharged should be considered in terms of the populations and habits of different organisms.

Although SSM does have the competence to undertake independent assessments, this must not detract from the requirement that SKB undertake and report an assessment that is fit for purpose. SSM should not accept bad science simply because it is not important in a safety case. Clarifications should continue to be sought from SKB where the review raises concerns.

Agenda

SSM Workshop on biosphere issues
21 October 2013

Venue: Freys Hotel, Bryggaregatan 12, Stockholm

8:30-8:45	Welcome, introduction and presentations of participants Mike Egan (SSM)
8:45-9:45	Modelling comparison of simple reference biosphere models with LDF models, Russell Walke (Quintessa)
9:45-10:15	Coffee
10:15-12:00	Modelling comparison of alternative biosphere models with LDF models and evaluation of selected parameter values used in the biosphere dose assessment, Richard Klos (Aleksandria Sciences), Anders Wörman (KTH) and George Shaw (University of Nottingham)
12:00-13:00	Lunch
13:00-14:00	Assessment of the derivation and use of K_d and CR values, Nicholas Beresford (CEH), Patrick Boyer (IRSN)
14:00-15:00	Assessment of radiological effects on non-human biota, Nicholas Beresford / Brenda Howard (CEH)
15:00-15:15	Coffee
15:15-17:00	Discussions for all (main findings from current review and suggestions for further review)

Appendix 2

List of Participants

Participant	Affiliation
Nick Beresford	Centre for Ecology & Hydrology, UK
Patrick Boyer	Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France
Gerald Kirchner	University Hamburg, Germany
Richard Klos	Aleksandria Sciences Ltd, UK
George Shaw	University of Nottingham, UK
Russell Walke	Quintessa Ltd, UK
Kai Hämäläinen	Radiation and Safety Authority (STUK), Finland
Roger Wilmot	Galson Sciences Ltd, UK
Anders Wörman	The Royal Institute of Technology (KTH), Sweden
Pål Andersson	Swedish Radiation Safety Authority (SSM), Sweden
Michael Egan	Swedish Radiation Safety Authority (SSM), Sweden
Maria Nordén	Swedish Radiation Safety Authority (SSM), Sweden
Shulan Xu	Swedish Radiation Safety Authority (SSM), Sweden

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The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 315 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

SE-171 16 Stockholm
Solna strandväg 96

Tel: +46 8 799 40 00
Fax: +46 8 799 40 10

E-mail: registrator@ssm.se
Web: stralsakerhetsmyndigheten.se