

ISSN 1404-0344

SKB TR-14-09

ID 1442446

Revised edition

Radionuclide transport and dose calculations for the safety assessment SR-PSU

Svensk Kärnbränslehantering AB

October 2015

Preface

This report compiles radionuclide transport and dose calculations for the scenarios included in the long-term safety assessment of the SFR repository for short-lived low- and intermediate level waste in Forsmark. Calculations of radionuclide release and transport from the repository to the biosphere are presented together with corresponding radiation doses to humans and non-human biota. The report forms part of the SR-PSU safety assessment, which supports SKB's licence application to extend SFR.

The report is authored by Per-Gustav Åstrand (Facilia AB), Per-Anders Ekström (Facilia AB), Thomas Hjerpe (Facilia AB) and Sven Keesmann (SKB). The main author of Chapter 8 is Benedict Jaeschke (SKB). Many others who have contributed at specific stages of the work are acknowledged in Section 1.3.2. The report has been reviewed by Russell Alexander (Bedrock Geoscience, UK), Jordi Bruno (Amphos 21 Consulting S.L., Spain), Maria Lindgren (Kemakta Konsult AB) and Mike Thorne (only first edition) (Mike Thorne Ltd., UK). Fredrik Vahlund, the project manager for the safety assessment SR-PSU, is responsible for the safety analysis. Eva Andersson is the project manager in the licensing phase of SR-PSU (starting January 2015).

This report is a revised edition compared to the report published in December 2014. This revised edition of the Radionuclide transport report presents results with an updated (increased) inventory of Mo-93 (SKBdoc 1481419) taken into account. In addition to this, there was also an update in the inventory for the *high inventory calculation case*. Some minor errors in the previous calculations has also been corrected including 1) the probabilistic calculation for the silo releases which had been interrupted after 90% of the iterations, in the global warming calculation case, has now been run correctly and 2) estimation of collective dose, where a data handling mistake caused a minor error in the previous calculation. Also typographical errors, linguistic errors and ambiguities in the report text, found during the update, have been corrected.

The calculation of exposure of non-human biota has not been updated in this revised edition as the previous calculation showed that the exposure of non-human biota is well below the screening limits, and the increased inventory of Mo-93 is not large enough to change this conclusion.

October 2015

Fredrik Vahlund

Project leader SR-PSU

Eva Andersson

Project leader SR-PSU

Abstract

This report describes the modelling of radionuclide transport and dose calculation for the post-closure safety assessment SR-PSU. The post-closure safety assessment is part of SKB's licence application to extend the repository for short-lived low- and intermediate level waste, SFR. The role of SR-PSU in the application is to demonstrate post-closure safety of SFR. A set of scenarios is described in the **Main report**. These scenarios are identified to cover credible future evolutions of the SFR repository and its environs. In the current report, the radiological consequences of the different scenarios have been estimated to provide a basis for the subsequent risk evaluation in the **Main report**. It is hence difficult to draw conclusions on fulfilling requirements on radiological safety solely on the results given in this report. The results are summarised and discussed as far as possible in Chapter 10.

This report presents the models and compiles a description of the calculation cases discussing aspects of input data and results. The presentation of the modelling focuses on the near-field (repository) and far-field (geosphere) while the modelling of the biosphere (surface system) is described in more detail in Saetre et al. (2013).

Characteristic for the approach for radionuclide transport and dose calculations in this assessment is the full coupling of near-field, far-field and biosphere. In the previous assessment, annual doses were calculated from far-field releases by means of dose conversion factors, which had been obtained from peak dose responses of the biosphere model to constant releases of radionuclides to the biosphere. The present approach, presented in Chapter 2, accounts for the release history relative to the development of the surface system in the dose assessment. The treatment of uncertainties in the assessment in general, and in the implementation of calculation cases in particular, is also addressed in Chapter 2.

Chapter 3 presents the radionuclide inventory and the selection of the radionuclides to account for in the transport modelling and dose calculations. A larger number of radionuclides are explicitly taken into account than in previous assessments of SFR. This is due to that the decommissioning waste will contain new radionuclides compared with existing operational waste, and that a simpler screening of radionuclides is applied in this analysis, aiming at only excluding the clearly insignificant radionuclides from the modelling. The identification of the most significant radionuclides is then made in conjunction with the evaluation of the modelling results.

Chapter 4 describes the calculation cases according to the scenario category which they belong to, i.e. main scenario, less probable scenario, combined (less probable) scenarios or residual scenarios.

The following chapters discuss the obtained results, focusing on annual effective doses and respective contributions from waste vaults and dominating radionuclides for calculation cases of the main scenario (Chapter 5), of the less probable scenarios and two of their combinations (Chapter 6), and of residual scenarios (Chapter 7). The discussion of peak (mean) annual effective dose of a calculation case is of particular interest because of its relevance for the risk analysis in the **Main report**. In addition, radionuclide releases from the near-field and far-field are also discussed. The calculation results are in general compared with the *global warming calculation case* of the main scenario. The comparison of peak releases from the far-field of an analysed calculation case with the *global warming calculation case* illustrates in many cases the impact of specific assumptions of a calculation case. Statistics describing the distribution of annual effective doses are reported for all probabilistically assessed calculation cases.

Absorbed dose rates to non-human biota (a number of reference organisms in terrestrial, marine and limnic ecosystems) are reported in Chapter 8. Absorbed dose rates have been calculated for most calculation cases. The calculations were made deterministically, using site-data where possible; a short analysis of probabilistically derived results was also made, for comparison.

Chapter 9 provides the description of the models for the near-field, far-field and biosphere, putting most emphasis on the near-field and far-field as the biosphere model is described in details in Saetre et al. (2013).

Chapter 10 provides a summary of results and gives an overview for the calculation cases of peak annual effective doses, with statistics describing the variance, and of contributions from radionuclides and waste vaults to peak annual dose. Results of a calculation case assessing the collective dose and absorbed dose rates to non-human biota are also summarised.

The appendices compile complementary input data (radionuclide inventories, far-field flows), additional information and complementary results justifying the implementation of models and calculation cases, the mathematical model for transfers in the far-field, supporting information for the modelling of radionuclide transport through concrete barriers and a compilation of results of all calculation cases for all radionuclides (peak releases from the near-field, peak releases from the far-field, peak annual effective dose). The second last part of the appendix provides a sensitivity analysis based on the probabilistic calculations for the *global warming calculation case*. The last part of the appendix provides a glossary of the terms used in the report.

Sammanfattning

Denna rapport beskriver modellering av radionuklidtransport och dosberäkning för den långsiktiga säkerhetsanalysen SR-PSU. Analysen av säkerhet efter förslutning är en del av SKB:s licensansökan för att bygga ut slutförvaret för kortlivat låg- och medelaktivt avfall, SFR. SR-PSU:s roll i ansökan är att visa säkerheten efter förslutning för SFR. I huvudrapporten för SR-PSU (**Main report**) beskrivs ett antal scenarier som identifierats för att täcka in möjliga framtida utvecklingar av förvaret och dess omgivning. I den här rapporten, har de radiologiska konsekvenserna av de olika scenarierna uppskattats som ett underlag till den efterföljande riskutvärderingen i huvudrapporten för SR-PSU (**Main report**). Slutsatser avseende uppfyllande av krav rörande radiologisk säkerhet kan därför inte enbart dras direkt från resultaten i denna rapport. Resultaten sammanfattas och diskuteras så långt det är möjligt i kapitel 10.

Den här rapporten innehåller en beskrivning av modellerna, av beräkningsfallen för modellering av radionuklidtransport och dosberäkningar, samt en sammanställning beräkningsresultat. Presentationen av modelleringen fokuserar på närområdet (förvar) och fjärrområdet (geosfär) medan modellering av biosfären (ytnära system) beskrivs närmare i Saetre et al. (2013).

Karakteristiskt för den valda modelleringsapproachen är kopplingen av närområde, fjärrområde och biosfär i en sammanhängande modellkedja. I den föregående analysen beräknades doserna genom att skala det beräknade radionuklidutsläppet från geosfären med dosfaktorer. Dosfaktorerna (Landskapsdosfaktorer eller Ekosystemdosfaktorer) beräknades genom att ett enhetsutsläpp applicerades på en biosfärmodell. Den nuvarande metoden, som beskrivs i kapitel 2, tar hänsyn till utsläppshistoriken i förhållande till utvecklingen av ytsystemet. Behandlingen av osäkerheter tas också upp i kapitel 2.

Kapitel 3 presenterar radionuklidinventariet och valet av radionuklider att ta hänsyn till i radionuklidtransport och dosberäkningen. Ett större antal radionuklider ingår i radionuklidtransport och dosberäkningen i denna analys jämfört med tidigare analyser av SFR. Detta beror på att avfall från avvecklingen av kärnkraftverken innehåller några nya radionuklider jämfört med befintligt driftavfall och att en enklare screening av radionuklider används i denna analys, med syftet att enbart identifiera och exkludera uppenbart icke-signifikanta radionuklider från modellering. Identifieringen av de mest signifikanta radionukliderna görs i samband med resultatutvärderingen.

Kapitel 4 beskriver beräkningsfallen utifrån de scenariokategorier som de tillhör, huvudscenariot, mindre troliga scenarier, kombinerade (mindre troliga) scenarier, eller restscenarier.

I de följande kapitlen diskuteras resultaten med fokus på den årliga effektiva dosen och bidragen från de olika förvarsdelarna och dominerande radionuklider för beräkningsfallen i huvudscenariot (kapitel 5), i de mindre sannolika scenarier och två av deras kombinationer (kapitel 6), och i restscenarierna (kapitel 7). Diskussion om maxvärden för den årliga effektiva dosen av särskilt intresse på grund av dess relevans för riskanalysen som görs i **Main report**. Förutom dosresultat diskuteras också utsläpp från närområdet och fjärrområdet. Beräkningsresultaten jämförs generellt med resultat från *beräkningsfallet med global uppvärmning* i huvudscenariot.

Absorberade doshastigheter till annan biota (ett antal referensorganismer i terrestra, marina och limniska ekosystem) presenteras i kapitel 8. Absorberade doshastigheter har beräknats för de flesta beräkningsfall. Beräkningarna utfördes deterministiskt och platsdata användes i största möjliga mån. En begränsad probabilistisk analys utfördes för jämförelse med de deterministiska resultaten.

I kapitel 9 ges en beskrivning av modellen för närområdet, fjärrområdet och biosfär. Eftersom biosfärmodellen diskuteras i detalj i Saetre et al. (2013) så är endast en översiktlig beskrivning av den presenterad här.

I kapitel 10 ges en sammanfattning av resultaten. Den innehåller en översikt av maxvärden för årliga effektiva doser för de olika beräkningsfallen med statistik över variansen. Det ges också en sammanställning av bidrag från specifika radionuklider och förvarsdelar till maxvärdet för de årliga effektiva doserna, resultat för ett beräkningsfall som uppskattat kollektivdosen och absorberade doshastigheter till annan biota.

I bilagorna sammanställs, 1) kompletterande indata, 2) ytterligare information och kompletterande resultat som motiverar genomförandet av modeller och beräkningsfall, 3) detaljer kring den matematiska modellen för geosfären, 4) underlag för modellering av radionuklidtransport genom betongbarriärer och 5) en sammanställning av resultaten av alla beräkningsfall för alla radionuklider (maximalt utsläpp från närområdet, maximalt utsläpp från fjärrområdet och maximala årliga effektiva dosen). Den näst sista bilagan presenterar resultat från en känslighetsanalys baserad på de probabilistiska beräkningarna för *beräkningsfallet med global uppvärmning* i huvudscenariot. Slutligen presenteras också en ordlista med förklaringar till de begrepp som används i rapporten.

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