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Review of Radionuclide Abstraction and Selection in the SKB Safety Case

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 i avgränsade frågor. I SSM:s Technical note-serie rapporteras resultaten från dessa konsultuppdrag.

Projektets syfte

Syftet med detta projekt är att granska SKB:s urval av radionuklider och utvärdera om det finns nuklider som inte har beaktats och som skulle kunna ha en betydelse för säkerhetsanalysen.

Författarnas sammanfattning

I denna rapport dokumenteras Center for Nuclear Waste Regultory Analyses:s (CNWRA:s) granskning av abstraktion och urval av radionuklider i Svensk Kärnbränslehantering AB:s (SKB:s) säkerhetsanalys. Detta arbete utgör en del av Strålsäkerhetsmyndighetens (SSM:s) granskning av SKB:s säkerhetsanalys för den långsiktiga säkerheten för ett slutförvar för använt kärnbränsle SR-Site. CNWRA har i synnerhet utvärderat aspekter som uteslutits från SKB:s metod för att utvärdera, välja och modellera individuella radionuklider och sönderfallskedjor med många radionuklider som märkbart skulle kunna påverka dosberäkningar.
I enlighet med uppdraget från SSM granskade CNWRA radionuklidtransportrapporten för säkerhetsanalysen SR-Site och rapporten om använt kärnbränsle för deponering i ett KBS-3 förvar. CNWRA beaktade också relevant information från andra kärnavfallsprogram och utvärderade förenklingar som SKB gjort i sönderfallskedjor.

CNWRA har jämfört SKB:s analys med analyser i andra kärnavfallsprogram och funnit att den uppsättning radionuklider som SKB använder är lik den som används i andra kärnavfallsprogram. Ytterligare detaljer kring SKB:s urval och abstraktion av radionuklider finns beskriven i denna rapport. CNWRA anser att SKB:s motiveringar och beräkningar för att utesluta vissa radionuklider är lämpliga ur ett tekniskt perspektiv, men CNWRA rekommenderar ändå SSM att eftersöka ytterligare information inom några få områden. Som en del av analysen av urans sönderfallskedjor, SSM bör fråga SKB om det finns skäl att anta ytterligare bidrag till närzonsutsläpp av ^{210}Pb pga. av frigörelse av ^{222}Rn gas från opåverkat bränsle. Klargöranden behövs kring användandet av antagandet radioaktiv jämvikt i säkerhetsanalysen. Beroende på avsaknad av tillgänglig information var det inte möjligt att verifiera om kortlivade nuklider så som ^{238}Ra, ^{210}Po och ^{239}Np har inkluderats i bestämningen av radiologiska doskoefficienter.

SSM bör därför efterfråga från SKB stödjande information om användningen av doskoefficienter inom säkerhetsanalysen. Det rekommenderas också att SKB begär SKB att ange ytterligare skäl för att motivera uteslutandet av ^{126}Sb, särskilt som dess närvaro understödjs av sönderfallet av ^{126}Sn. I syn-

nerhet, det behövs en diskussion om den förväntade sorptionskoefficienten för ^{126}Sb till berget som möjliggör en jämförelse med sin långlivade och starkt sorberande modernuklid ^{26}Sn. Möjlig frigörelse av radionuklider sorberade på inkapslingsytor (crud) bör utvärderas och jämföras med bidrag från andra radionuklider i fallet med tidiga kapselbrott.

Projektinformation
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Diarienummer avrop: SSM2013-2633
Aktivitetsnummer: 3030012-4068

SSM perspective

Background

The Swedish Radiation Safety Authority (SSM) reviews the Swedish Nuclear Fuel Company's (SKB) 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 on specific issues. The results from the consultants' tasks are reported in SSM's Technical Note series.

Objectives of the project

The objective of this assignment is to explore SKB's selection of radionuclides and to evaluate if any unaccounted radionuclide could play a role in any aspect of the safety case.

Summary by the authors

As part of the Swedish Radiation Safety Authority (SSM) review of the Swedish Nuclear Fuel and Waste Management Company (SKB) SR-Site safety assessment for a spent nuclear fuel repository in Sweden, this technical note documents the Center for Nuclear Waste Regulatory Analyses (CNWRA®) review of the abstraction and selection of radionuclides in the SKB safety case. Specifically, CNWRA evaluated whether the SKB approach to assess, select, and model individual radionuclides and decay chains of multiple radionuclides omitted aspects that could significantly affect dose results. In accordance with the SSM assignment, CNWRA reviewed the Radionuclide Transport Report for the Safety Assessment SR-Site and Spent Nuclear Fuel for Disposal in the KBS 3 Repository. CNWRA also consulted relevant technical information from other nuclear waste programs and evaluated simplifications made by SKB in the radioactive decay chains.

CNWRA compared the SKB analyses to other nuclear waste programs and found that the set of radionuclides selected by SKB is similar to other programs. Additional details on the selection and abstraction of radionuclides by SKB are described in the technical note. CNWRA finds the SKB supporting rationale and calculations to be technically appropriate for most of the excluded radionuclides but recommends that SSM seek additional information in a few areas. As part of the uranium decay chain analysis, SSM may ask SKB to address additional contributions to near field releases of ^{210}Pb due to the escape of ^{222}Rn gas from non-degraded waste. Clarifications are needed on the incorporation of the secular equilibrium assumption in the performance assessment. Because available information was insufficient to verify the inclusion of short lived radionuclides, such as ^{238}Ra, ^{210}Po, and ^{239}Np in the determination of radiological dose coefficients, SSM should ask SKB to provide supporting information on the dose coefficient values used in the safety assessment. It is also recommended that SSM request SKB to provide a rationale to support the exclusion of ^{126}Sb, especially because its presence is supported by the decay of ^{126}Sn. In particular, discussion of the

anticipated sorption partitioning coefficient for ^{126}Sb to the rock would allow a comparison to be made with its long lived and highly sorbing parent radionuclide, ^{126}Sn. Potential releases of radionuclides deposited on cladding surfaces (crud) should be assessed and compared to other radionuclide contributions arising from early canister failures.

Project information
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Technical Note 63

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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

This technical note documents Center for Nuclear Waste Regulatory Analyses (CNWRA®) input to the Swedish Radiation Safety Authority (SSM) main review phase of the Swedish Nuclear Fuel and Waste Management Company (SKB) SR-Site safety assessment for a spent nuclear fuel repository in Sweden. For this task, CNWRA reviewed the selection and abstraction of radionuclides in the SR-Site safety assessment as part of the SSM framework agreements covering Performance Assessment and the review area on independent modelling of radionuclide transport.

As highlighted in the assignment description, the main review phase activities are targeted on specific issues identified by SSM that directly or indirectly support compliance judgments to be rendered by SSM. The main objective of this independent assessment of SKB's selection and abstraction of radionuclides was to identify if there is a reasonable expectation that any unaccounted radionuclide could significantly influence the results of the SKB safety case. The scope of the assignment included the mandatory review of two reports: *Radionuclide transport report for the safety assessment SR-Site*, TR–10–50 (SKB, 2010a) and *Spent nuclear fuel for disposal in the KBS-3 repository*, TR–10–13 (SKB, 2010b). By consulting technical information from other nuclear waste management programs, CNWRA compared the set of radionuclides included in other performance assessments to the SKB selection of radionuclides. From those comparisons, individual differences were identified and evaluated. In accordance with a specific SSM request, CNWRA assessed the degree to which individual unaccounted radionuclides could provide a significant contribution to calculated radiological doses under specific conditions, scenarios, or timeframes. The review also considered potential influences from simplifications made by SKB in the radionuclide decay chains. Merits and any weaknesses of the SKB assessments are also discussed in the CNWRA evaluation. Because the evaluation identified a few specific requests for additional information or clarifications instead of broad requests, independent calculations were not performed as part of this main review phase activity. References to relevant aspects of CNWRA assessments completed during the initial review phase are included as appropriate.

As previously introduced, the review follows the assignment and specific questions provided by SSM. In this technical note, the review is documented in three separate sections addressing: the radionuclide selection (Section 2), abstraction of selected radionuclides (Section 3), and overall assessment (Section 4). Radionuclide half-lives reported in this technical note were obtained from the International Commission on Radiological Protection (1996).

2. Selection of Radionuclides

A fundamental objective of geologic disposal is to contain spent nuclear fuel in engineered disposal canisters for long time periods so that the release of radioactive material and potential human exposures are prevented or minimised. Performance assessment models are developed to estimate the radiological risk to members of the public from any spent nuclear fuel radionuclides that migrate to and enter the biosphere. Spent nuclear fuel contains hundreds of radionuclides. The amount of an individual radionuclide, in terms of its radioactivity or mass, changes over time due to radioactive decay and in-growth. Computational tracking of all radionuclides is unnecessary because some radionuclides are present in such minute amounts that they have no effect on calculated releases and doses. The common practice of radionuclide selection refers to the identification of those radionuclides that are deemed to be of potential importance to the performance assessment calculations. Selected radionuclides are included in the performance assessment.

2.1. Selection of radionuclides: SKB's presentation

SKB based the radionuclide selection on inventory, half-life, radiotoxicity, and shared solubility (SKB, 2010a, page 37). SKB calculated the radionuclide inventories for the spent nuclear fuel matrix and for all other materials in the assembly referred to as "construction materials" (SKB, 2010b, Section 6.2.2). For the fuel matrix, SKB used the well known computer code, ORIGEN-S. Other computer codes were used for the inventory calculations in construction materials and crud. SKB considered uncertainties in the inventory calculations (SKB, 2010b, Sections 6.2.6 and 6.2.7), reported good agreement with measurements (SKB, 2010b, Table 6-14), and concluded that the larger uncertainties in transuranic radionuclide activities would be adequately addressed in the inventory calculations by the selection of conservative burnup values (SKB, 2010b, Section 6.2.6).

For a large majority of the radionuclides, activities in fuel dominated the radionuclide inventory. For the main categories of spent nuclear fuel, SKB reported greater contributions from construction materials and crud to the total inventories for several radionuclides: ^{108m}Ag, ^{14}C, ^{93}Mo, ^{93m}Nb, ^{94}Nb, ^{59}Ni, ^{63}Ni, and ^{121m}Sn (SKB, 2010b, Table C-2). In TR–10–13 (SKB, 2010b, page 52), SKB states: "The content of Co-60 is of special interest since it is the dominant radiation source for the activation products." Calculations of activated products and crud deposits on the surface of spent nuclear fuel cladding were performed and incorporated into the radionuclide inventory tabulations (SKB, 2010b, Appendix C).

As part of the radionuclide selection process, SKB intentionally disabled several mitigating features and processes and performed calculations for a hypothetical case with a large initial defect in the canister to examine the potential influence from short-lived radionuclides (SKB, 2010a, Appendix D). For fission and activation products, SKB highlighted radiotoxicity and half-life in the radionuclide screening process (SKB, 2010a, Figure D-1). Screening arguments were also articulated by SKB for radionuclide members in the four main decay chains (SKB, 2010a, Section D.3).

2.2. Motivation of the assessment

The radionuclide selection process was reviewed to assure that safety-relevant radionuclides were included in the SKB performance assessment and the screening justification provided by SKB was sufficient for excluding specific radionuclides based on their minor potential to influence results of performance assessment modelling scenarios.

2.3. The consultants' assessment

The CNWRA consultants' evaluation of the SKB screening process included comparisons of the set of included radionuclides for SR-Site to radionuclide selections in other nuclear waste management programs. Radionuclides on the surfaces of cladding and the pulse release of fission gases were also addressed.

2.3.1. Comparison to radionuclide selections in other nuclear waste management programs

As further explained in this subsection and shown in Table 1, radionuclide sets from other nuclear waste management programs were compared to the set of radionuclides selected by SKB.

United States Total System Performance Assessment – USDOE

The radionuclide screening for Yucca Mountain (Sandia National Laboratory, 2007a) was compared with SKB's screening for SR-Site. The comparison was performed to identify any radionuclides not in the SKB list. If in such a comparison certain radionuclides stand out as not being part of the SR-Site list, then further assessment of those radionuclides could determine whether or not they should be considered by SKB in SR-Site analyses.

As the implementer for repository development in the United States, the United States Department of Energy (USDOE) conducted a radionuclide screening analysis for Yucca Mountain by compiling a comprehensive list of the radionuclides in various waste forms slated for disposal and removing radionuclides from the list that were unlikely to significantly contribute to calculated radiation doses. Although each organization had different responsibilities in the United States repository program for high-level radioactive waste disposal, USDOE is one of several organizations that carried out radionuclide screening as a part of total-system performance assessments—the others being the United States Nuclear Regulatory Commission (USNRC) and Electric Power Research Institute (EPRI). In this technical note, radionuclide screening by the USNRC is described next. Because consideration of radionuclide screening by both USDOE and USNRC provides a sufficient representation of the United States program and sound basis for comparison to the SKB results, the EPRI radionuclide screening analysis is not presented. Furthermore, USNRC reviewed earlier screening analyses performed by the USDOE and provided comments, which were later addressed by the USDOE. An international panel involving the Nuclear Energy Agency and International Atomic Energy Agency (IAEA) also reviewed the USDOE Site Recommendation and provided comments on the radionuclide selection (OECD and IAEA, 2002).

In the screening process, USDOE used the generic screening factors from the National Council on Radiation Protection and Measurements as documented in the NCRP-123 report (NCRP, 1996). In the United States, NCRP reports are understood

Table 1: Comparison of radionuclides selected in SR-Site with other nuclear waste programs. U.S. Nuclear Regulatory Commission and CNWRA in an independent total-system performance assessment (Mohanty et al., 2002, Table 19-1), U.S. Department of Energy in any main scenario of the total system performance assessment (Sandia National Laboratory, 2007a), and the Japan Nuclear Cycle Development Institute in the biosphere model of the Japanese safety assessment (Japan Nuclear Cycle Development Institute, 2000, Table 5.3.3-2).

Radionuclide	SKB SR-Site	U.S. Nuclear Regulatory Commission	U.S. Department of Energy	Japan Nuclear Cycle Development Institute
^{3}H	**Included**	Excluded	Excluded	Excluded
^{14}C	**Included**	**Included**	**Included**	Excluded
^{36}Cl	**Included**	**Included**	**Included**	Excluded
^{59}Ni	**Included**	**Included**	Excluded	Excluded
^{63}Ni	**Included**	**Included**	Excluded	Excluded
^{79}Se	**Included**	**Included**	**Included**	**Included**
^{90}Sr	**Included**	**Included**	**Included**	Excluded
^{93}Zr	**Included**	**Included**	Excluded	**Included**
^{93}Mo	**Included**	**Included**	Excluded	Excluded
^{93m}Nb	**Included**	Excluded	Excluded	**Included**
^{94}Nb	**Included**	**Included**	Excluded	**Included**
^{99}Tc	**Included**	**Included**	**Included**	**Included**
^{107}Pd	**Included**	**Included**	Excluded	**Included**
^{108m}Ag	**Included**	**Included**	Excluded	Excluded
^{113m}Cd	**Included**	Excluded	Excluded	Excluded
^{121m}Sn	**Included**	**Included**	Excluded	Excluded
^{126}Sn	**Included**	**Included**	**Included**	**Included**
^{129}I	**Included**	**Included**	**Included**	Excluded
^{135}Cs	**Included**	**Included**	**Included**	**Included**
^{137}Cs	**Included**	**Included**	**Included**	Excluded
^{151}Sm	**Included**	**Included**	Excluded	**Included**
^{152}Eu	**Included**	Excluded	Excluded	Excluded
^{166m}Ho	**Included**	Excluded	Excluded	Excluded
^{210}Pb	**Included**	**Included**	**Included**	**Included**
^{210}Po	Excluded, secular equilibrium assumed (SKB, 2010a)	Excluded	Excluded	**Included**
^{226}Ra	**Included**	**Included**	**Included**	**Included**
^{227}Ac	**Included**	**Included**	**Included**	**Included**
^{228}Ra	Excluded, secular equilibrium assumed (SKB, 2010a)	Excluded	**Included**	**Included**
^{228}Th	Excluded, secular equilibrium assumed (SKB, 2010a)	Excluded	Excluded	**Included**
^{229}Th	**Included**	**Included**	**Included**	**Included**
^{230}Th	**Included**	**Included**	**Included**	**Included**
^{231}Pa	**Included**	**Included**	**Included**	**Included**
^{232}Th	**Included**	Excluded	**Included**	**Included**
^{232}U	Excluded (SKB, 2010a, Table D-1 and Figure D-4)	**Included**	**Included**	Excluded
^{233}Pa	Refer to Section 3.3.2 (initial activity added to ^{233}U inventory)	Excluded	Excluded	**Included**
^{233}U	**Included**	**Included**	**Included**	**Included**
^{234}U	**Included**	**Included**	**Included**	**Included**
^{235}U	**Included**	**Included**	**Included**	**Included**
^{236}U	**Included**	**Included**	**Included**	**Included**

Radionuclide	SKB SR-Site	U.S. Nuclear Regulatory Commission	U.S. Department of Energy	Japan Nuclear Cycle Development Institute
^{237}Np	**Included**	**Included**	**Included**	**Included**
^{238}Pu	**Included**	**Included**	**Included**	Excluded
^{238}U	**Included**	**Included**	**Included**	**Included**
^{239}Pu	**Included**	**Included**	**Included**	**Included**
^{240}Pu	**Included**	**Included**	**Included**	**Included**
^{241}Pu	Refer to Section 3.3.2 (initial activity added to ^{241}Am inventory)	**Included**	**Included**	**Included**
^{241}Am	**Included**	**Included**	**Included**	**Included**
^{242}Pu	**Included**	**Included**	**Included**	**Included**
^{242m}Am	**Included**	**Included**	Excluded	Excluded
^{243}Cm	Refer to Section 3.3.2 (initial activity added to ^{239}Pu inventory)	**Included**	Excluded	Excluded
^{243}Am	**Included**	**Included**	**Included**	**Included**
^{244}Cm	Refer to Section 3.3.2 (initial activity added to ^{240}Pu inventory)	**Included**	Excluded	Excluded
^{245}Cm	**Included**	**Included**	**Included**	**Included**
^{246}Cm	**Included**	**Included**	Excluded	**Included**

to be sources of established scientific bases and data for radiation protection. NCRP-123 describes simple models to assess doses from radionuclide releases to the environment and includes screening factors that convert radionuclide concentrations in water and air to radiological doses. The screening models in NCRP-123 are conservative by design, and it is understood that if compliance can be demonstrated using those models, then further complexity in modelling would not be necessary in general. Nevertheless, USDOE adjusted some of the NCRP screening factors (mostly for air exposure pathways) by replacing the NCRP generic usage factors with usage factors specific to Yucca Mountain that accounted for biosphere influences on modelled receptor characteristics for the local population.

USDOE calculated ‘average’ and ‘outlying’ (or maximum) radionuclide activities as functions of time considering waste stream characteristics such as enrichment, burn-up, and age. For groundwater transport scenarios, DOE developed nine screening sets according to transport characteristics (i.e., solubility and sorption) of each radioelement. Radionuclides within a set were ranked according to the product of the radionuclide activity associated with the inventory and the screening factor (i.e., the factor for converting radionuclide concentration in water and air to related doses) for the radioelement without regard to transport characteristics. The USDOE screening process for Yucca Mountain led to retaining 32 radionuclides for the performance assessment. The screening included two time periods (100–10,000 years and 10,000–100,000 years) and two scenario groups for: (1) nominal, human-intrusion, and intrusive igneous scenarios and (2) eruptive igneous scenarios. Only Group 1 is relevant for comparison with the SKB’s selection because Group 2 pertains to volcanic (eruptive) disruption of the repository and airborne release of radioactive material. For Group 1, 24 and 28 radionuclides were considered relevant to the time periods of 100–10,000 years and 10,000–1,000,000 years, respectively. Table 1 lists the 32 radionuclides derived from these two time periods and included by the DOE in its analyses.

USDOE analyses also included radionuclides for reasons other than potential contribution to radiological dose. Specifically, ^{226}Ra and ^{228}Ra were screened in because the TSPA calculation of their combined activities is required for regulatory

compliance demonstration. Radionuclides such as ^{245}Cm and ^{241}Pu were screened in because they contributed to the inventory of screened-in decay progeny. OECD and IAEA (2002) cited reference case considerations from 10 repository performance assessment studies. Though these studies varied with respect to waste form, geologic media, repository concept, and purpose for the assessment, there were many similarities in influential variables—initial waste inventory being one of them. By comparison, the USDOE radionuclide list included radionuclides in the OECD list, except for ^{94}Nb and ^{107}Pd that USDOE had screened out, as well as three radionuclides that were not in the OECD list (2002).

Table 1 shows a side-by-side comparison between the radionuclides selected by the USDOE for Yucca Mountain and by SKB for SR-Site. Table 1 shows that the SKB list includes all radionuclides included by USDOE except ^{228}Ra and ^{232}U. Further discussion of these two radionuclides is presented in Section 3 of this technical note. Compared to the USDOE list of included radionuclides for Yucca Mountain, SKB has included 13 additional radionuclides for a total of 45 radionuclides. Of these 13 radionuclides, ten radionuclides are considered by the SKB to be less important or potentially important in the what-if case with an initial canister defect (growing pinhole scenario). In SKB's results, none of these ten radionuclides influenced total dose significantly in the what-if scenario cases. Despite the added USDOE consideration of intrusive igneous activity that is not relevant to the SR-Site analysis, SKB's radionuclide list is still more inclusive, which provides further confidence that the SKB analysis adequately captures the set of important radionuclides.

United States Total-system Performance Assessment – USNRC

Forty three radionuclides were considered by the NRC and CNWRA in the total-system performance assessment (TPA) Version 4.0 code (Mohanty et al., 2002, Table 19-1). Inventories of these 43 radionuclides per unit spent nuclear fuel mass have been plotted for the time period between 10 and 1,000,000 years following removal from the reactor (Mohanty et al., 2002, Figure 3-9). These inventories were consistent with the SKB inventories at the time of emplacement (SKB, 2010b, Appendix C), especially when differences in spent fuel age were accounted for. As presented in Table 1, all but one radionuclide, ^{232}U, was also included in the SKB assessment. The CNWRA consultants reviewed the SKB screening rationale for ^{232}U and agree that separate modelling of ^{232}U is not necessary. ^{232}U is not a significant contributor to the total uranium mass or radioactivity. Compared to other radionuclides in the decay chain, SKB adequately demonstrated that ^{232}U contributions to radiological dose are negligible. No issues were identified from this comparison.

Japanese Performance Assessment

CNWRA investigated the radionuclides modelled in the Japanese biosphere assessment along with decay progeny assumed to be in secular equilibrium. The Japanese safety assessment assumed that ^{126m}Sb and ^{126}Sb were in equilibrium with ^{126}Sn for all biosphere components (Japan Nuclear Cycle Development Institute, 2000, Table 5.3.3-2). The radioactive decay of the long-lived parent radionuclide, ^{126}Sn, will create persistent concentrations of short-lived decay products, ^{126m}Sb and ^{126}Sb. The assumption that ^{126m}Sb and ^{126}Sb are in secular equilibrium with ^{126}Sn does not appear to be included in the SKB modelling (2010a, Table 4-6). In contrast to the Japanese treatment for inclusion at secular equilibrium with ^{126}Sn, the two decay products were not included by the U.S. Department of Energy in the

calculation of biosphere dose conversion coefficient for ^{126}Sn (Sandia National Laboratory, 2007b, Table 6.11-7). With half-lives less than 180 days, these two radionuclides were shown to be only marginally significant in the radionuclide classification scheme (Sandia National Laboratory, 2007a). The U.S. Department of Energy did not track, calculate doses for, or explicitly account for ^{126m}Sb and ^{126}Sb in the performance assessment but considered them as screened-in radionuclides because the long-lived parent radionuclide ^{126}Sn was included. The decay of ^{126}Sn (half-life of 100,000 years) will produce ^{126}Sb (half-life of 12.4 days) over long time frames. Separate consideration of ^{126m}Sb as an intermediate radionuclide, between ^{126}Sn and ^{126}Sb in the decay chain, is not recommended because the half-life of ^{126m}Sb is very short (less than 1 hour) and its ingestion dose coefficient is significantly smaller than the other two radionuclides.

Although the lack of site-specific information on migration parameters for antimony (Sb) prevented an unequivocal conclusion being reached in this technical note on the potential significance of ^{126}Sb, several factors that bear on its relative significance are discussed. The ingestion dose coefficient for ^{126}Sn exceeds the dose coefficients for ^{126m}Sb and ^{126}Sb (International Commission on Radiological Protection, 1996, Table A.1). The branching ratio for internal transition decay of ^{126m}Sb to ^{126}Sb (Shleien et al., 1998, Table 8.13) results in a lower equilibrium activity for ^{126}Sb, compared to^{126}Sn and ^{126m}Sb. Due to the previously stated lack of site-specific migration information for ^{126}Sb, the extent to which its behaviour is similar to either selenium or tin is uncertain. Performance assessment analyses show that ^{79}Se is an important radionuclide, whereas ^{126}Sn is not (SKB, 2010a). Instantaneous release and corrosion release fractions are higher for ^{79}Se compared to ^{126}Sn (SKB, 2010a, Table 3-4), and less sorption to the rock is modelled for ^{79}Se compared to ^{126}Sn (SKB, 2010a, Table 2-4). The disposed radiotoxicity of ^{126}Sn is approximately one order of magnitude greater than that of ^{79}Se (SKB, 2010a, Figure D-1), and the ingestion dose coefficient for ^{126}Sb is about half of the ^{126}Sn value. In light of the lack of site-specific information on sorption partitioning coefficient for antimony to the rock, SKB should be requested to provide additional rationale to support the exclusion of ^{126}Sb.

2.3.2. Radionuclides deposited on cladding surfaces

As quoted in Section 2.1.1, the importance of ^{60}Co as a dominant radiation source was noted by SKB (2010b, Section 6.2.7). However, contributions of ^{60}Co deposited on the surfaces of cladding to releases from early canister failures do not appear to have been accounted for by SKB in the radionuclide selection process. Two radionuclides for crud, ^{60}Co and ^{55}Fe, were analyzed by the USDOE for preclosure repository operations and included in the radionuclide inventory on the surfaces of cladding (U.S. Department of Energy, 2008, Table 24).
It is unclear if the total radiotoxicities of ^{60}Co and ^{55}Fe used for screening (SKB, 2010a, Figure D-1 for fission and activation products) accounted for the activity on cladding. More importantly though, the potential for higher release rates from cladding surfaces compared to spent fuel dissolution was not factored into the screening logic. Due to half-lives of 5.27 years for ^{60}Co and 2.70 years for ^{55}Fe, further radioactive decay, during the time between emplacement and canister failure, will result in lower activities on cladding surfaces (and in the fuel). At early canister failure times, the increased release rate from cladding surfaces may result in a

significant release of radionuclides compared to the instantaneously accessible fraction of radionuclides that has been assumed by SKB to be rapidly dissolved in water and released from the canister. Because the fuel dissolution rate of 10^{-7} per year does not apply to the release of radionuclides on the surfaces of cladding, higher fractional release rates of crud radionuclides may occur from breached canisters. Due to their shorter half-lives, the influence of crud radionuclides on near field releases, far field releases, and biosphere doses will be limited to scenarios with very early (<50 years) canister failures, which are analogous to a hypothetical case to support the radionuclide selection (SKB, 2010a, Section D.1, Figure D-2). Radioactive decay during groundwater transport would further reduce the activity of crud radionuclides reaching the biosphere. The relatively short travel times to the biosphere in SR-Site (SKB, 2010a, Table 4-3) allow the possibility that crud radionuclides rapidly released from cladding surfaces could influence the results for scenarios with very early canister failures. SKB should supplement existing information on radionuclide screening and selection with an assessment of radionuclides deposited on cladding surfaces.

The set of radionuclides used by the U.S. Department of Energy for assessing radiological consequences from potential releases of radioactive material during preclosure repository operations was also reviewed for further insights on potential short-lived radionuclides at the time of emplacement. For a spent nuclear fuel age of 10 years, ^{90}Sr and ^{90}Y contribute substantially to the total radioactivity (U.S. Department of Energy, 2008, Tables 6 and 7). This point is consistent with the SKB assessment that showed ^{90}Sr providing the greatest contribution to the total radiotoxicity from fission and activation products in spent nuclear fuel. Because ^{90}Y (half-life of 2.67 days) is short lived, has a significantly smaller ingestion dose coefficient compared to ^{90}Sr, and is expected to have a lower solubility and greater geosphere sorption compared to ^{90}Sr, CNWRA concludes that the SKB decision to neglect the contribution of ^{90}Y would not lead to underestimations in total dose, even for early release scenarios. No additional issues were identified from this review.

2.3.3. Pulse release of fission gas

During the initial review phase, radon pulse releases were evaluated (Benke and LaPlante, 2012, Sections 3.1 and 3.2). For spent nuclear fuel with ages of approximately 5 or 10 years (U.S. Department of Energy, 2008, Table 7), the gaseous fission product with the greatest inventory is ^{85}Kr. Unlike ^{222}Rn that is continuously produced, the inventory of ^{85}Kr (half-life of 10.7 years) reduces over time due to radioactive decay. Although initial inventories of ^{85}Kr can be large depending on the age of spent nuclear fuel, exposure times to a dissipating pulse release of ^{85}Kr would be very brief compared to potential prolonged exposures from the continuously produced ^{222}Rn, and the ^{85}Kr dose coefficient for submersion of 2.1×10^{-11} Sv/day per Bq/m^3 (International Commission on Radiological Protection, 1994, Annexe D) is considerably less than the inhalation dose coefficient for ^{222}Rn. As a result, pulse releases of fission gases or the direct vapour phase transport of other radionuclides from spent nuclear fuel to the biosphere would not be expected to exceed estimated doses in the stylized calculations for ^{222}Rn and its decay progeny, and therefore, no additional radionuclides are recommended for further evaluation from these pathways.

3. Abstraction of Selected Radionuclides

The abstraction of selected radionuclides refers to the incorporation of "included" radionuclides into the performance assessment. While the radionuclide selection addressed in the previous section applies to "which" radionuclides are included, the abstraction discussed in this section pertains to "how" the radionuclides are included.

3.1. Abstraction of selected radionuclides: SKB's presentation

Forty-five radionuclides were incorporated by SKB into the abstracted modelling for the SR-Site safety case (SKB, 2010a, Section 3.1). SKB prepared inventory tabulations for the 45 radionuclides and accounted for differences in spent nuclear fuel type (SKB, 2010b, Appendix C).

3.1.1. Abstracted modelling of main radioactive decay chains

SKB simplified the four main decay chains and presented supporting calculations for decay chain radionuclides (SKB, 2010a, Section D.3). The uranium series, thorium series, actinium series, and neptunium series are the four main decay chains:

- Uranium series originates with primary radionuclides ^{246}Cm and ^{242m}Am/^{242}Am in two branches that combine at ^{234}U.
- Thorium series originates with primary radionuclide ^{244}Cm and includes contributions from the decay of ^{232}U into ^{228}Th.
- Actinium series originates with primary radionuclides ^{243}Am and ^{243}Cm in two branches that combine at ^{239}Pu.
- Neptunium series originates with primary radionuclide ^{245}Cm.

SKB presented details on the full and simplified decay chains (2010a, Appendix D) along with remarks on radionuclide screening and treatment in the transport calculations.

3.1.2. Incorporating initial activities for excluded radionuclides

SKB added the initial activities of four "excluded" radionuclides with shorter half-lives, ^{244}Cm, ^{241}Pu, ^{243}Cm, and ^{233}Pa, to the inventories of their progeny (SKB, 2010a, Section 3.1).

3.1.3. Dose coefficient selection

General statements regarding equilibrium assumptions were included in SKB documentation (e.g., SKB, 2010a, Appendix D). A table of nine parent radionuclides with decay progeny assumed to be in secular equilibrium was also presented (SKB, 2010a, Table 4-6). Refer to Benke and LaPlante (2012, page 13) for additional statements and information highlighted on this topic during the initial review phase.

3.2. Motivation of the assessment

Aspects of the abstraction of selected radionuclides were reviewed to provide confidence that the SKB performance assessment modelling was consistent with available, relevant technical information and would not underestimate calculated doses. Decay chains were reviewed to assess if the simplifications made by SKB would cause significant dose contributions to be missed in the safety case results. CNWRA also performed an evaluation to determine if non-conservative estimates of radiological doses would be expected from the SKB approach, which incorporated the initial inventories of those radionuclides into the activities of their decay progeny, compared to an alternative modelling approach that would have included those shorter-lived radionuclides. A dose coefficient review was performed to verify that the dose coefficient values used by SKB were consistent with values published by scientific organizations and reflected the modelling assumptions for short-lived decay progeny and secular equilibrium.

3.3. The consultants' assessment

The CNWRA consultants' assessment of the abstraction of selected radionuclides included an evaluation of the SKB simplifications in modelling the four main radioactive decay chains. The review addressed specific radionuclides that were not selected for inclusion in the SR-Site model but whose initial activities were assigned to radionuclides included in the model. CNWRA also considered the SKB selection of radiological dose coefficients and related assumptions on radioactive equilibrium.

3.3.1. Abstracted modelling of main radioactive decay chains

CNWRA reviewed the simplifications made by SKB in the thorium, neptunium, uranium, and actinium decay chains.

Thorium decay chain

For the thorium decay chain, SKB assumed that ^{228}Ra, ^{228}Th, and ^{224}Ra decay progeny were in secular equilibrium with the long-lived parent radionuclide ^{232}Th (SKB, 2010a, Table 4-6). Because SKB listed ^{228}Ra, ^{228}Th, and ^{224}Ra as excluded (SKB, 2010a, Table D-1), SKB should clarify how the secular equilibrium assumption was incorporated into the performance assessment (refer to Section 3.3.3 in this technical note for additional discussion). Based on a half-life of 6.13 hours for ^{228}Ac and its small ingestion dose coefficient, CNWRA finds that not accounting for ^{228}Ac in the thorium decay chain and in the secular equilibrium assumptions for the ^{228}Th parent (SKB, 2010a, Table 4-6) is a reasonable simplification. Because the initial activity of ^{232}U is many orders of magnitude greater than that of ^{232}Th in spent nuclear fuel at the time of emplacement, contributions to ^{228}Th from ^{232}U decay will substantially exceed those from ^{232}Th decay for at least thousands of years. Although the assumed secular equilibrium assumption is invalid during this early timeframe, SKB assessed radionuclide contributions using the simplified decay chain and showed ^{228}Th contributions that accounted for the decay contributions from ^{232}U. Because ^{228}Th and ^{232}U provided insignificant contributions to the total radiological dose from the decay chain, excluding ^{228}Th and ^{232}U would not be expected to underestimate dose. Considering available information on radioactive half-lives and

ingestion dose coefficients, CNWRA finds that the simplifications made by SKB to the thorium decay chain (SKB, 2010a, Figure D-3 and Table D-1) are reasonable for estimating dose.

Neptunium decay chain

For the neptunium decay chain, SKB assumed the following secular equilibrium pairings: ^{241}Pu with its ^{245}Cm parent, ^{233}Pa with its ^{237}Np parent, and ^{225}Ra and ^{225}Ac with the ^{229}Th parent (SKB, 2010a, Table 4-6). Although ^{241}Pu and ^{233}Pa were excluded from individual consideration, their inventories were added to the initial inventories of ^{241}Am and ^{233}U, respectively (SKB, 2010a, Table D-2). This simplification is discussed further in Section 3.3.2. Because SKB listed ^{225}Ra and ^{225}Ac as excluded (SKB, 2010a, Table D-2), SKB should clarify how the secular equilibrium assumption was incorporated into the performance assessment. Considering available information on radioactive half-lives and ingestion dose coefficients, CNWRA finds that the simplifications made by SKB to the neptunium decay chain (SKB, 2010a, Figure D-7 and Table D-2) are reasonable for estimating dose.

Uranium decay chain

For the uranium decay chain, SKB assumed that secular equilibrium was established for ^{234}Th with its ^{238}U parent, for ^{210}Bi and ^{210}Po with the ^{210}Pb parent, and for ^{242}Cm with the longer lived ^{242m}Am parent (SKB, 2010a, Table 4-6). Because SKB also listed ^{234}Th, ^{210}Bi, and ^{210}Po as excluded (SKB, 2010a, Table D-3), SKB should clarify how the secular equilibrium assumption was incorporated into the performance assessment. Based on a half-life of 16.0 hours for ^{242}Am and its small ingestion dose coefficient, CNWRA finds that not separately accounting for ^{242}Am in the uranium decay chain (SKB, 2010a, Table 4-6) is a reasonable simplification. Not accounting for ^{242}Cm and assigning its initial inventory to ^{238}Pu for early releases is appropriate because the dose coefficient for ^{238}Pu exceeds the value for ^{242}Cm (SKB, 2010a, Table D-3) and instantaneous release and corrosion release fractions, solubilities, and sorption partitioning coefficients are similar or equal for curium and plutonium (SKB, 2010a, Tables 2-4 and 3-4). CNWRA finds neglecting the small branching fractions in the uranium decay chain to ^{234}Pa (0.13%), ^{218}At (0.02%), ^{210}Tl (0.021%), and 0.00013 ^{206}Tl (Shleien et al., 1998, Table 8.9) to be inconsequential in the SKB analysis.

An issue pertaining to the abstraction of ^{222}Rn, a noble gas in the uranium decay chain, was raised during the initial review phase (Pensado and Mohanty, 2012, pp. 33 and 36). The issue relates to an additional contribution to near-field releases of ^{210}Pb due to the escape of ^{222}Rn gas from non-degraded waste. The release of ^{222}Rn gas from non-degraded waste would effectively correspond to an instantaneous release fraction and continuous additional release flux due to the continuous production of ^{222}Rn gas and decay progeny from waste in the failed container. In the SR-Site assessment, instantaneous release and corrosion release fractions are zero for ^{210}Pb (SKB, 2010a, Table 3-4). SKB should assess the release of ^{222}Rn gas from non-degraded waste, re-evaluate previously calculated results that could be sensitive to the additional releases, and ascertain any influences on radionuclide screening and abstraction. For the decay progeny of ^{222}Rn, ^{210}Pb has the longest half-life, 22.3 years. This half-life seems sufficiently long in light of

calculated groundwater travel times (SKB, 2010a, Table 4-3) that ^{222}Rn releases from the canister could result in non-negligible groundwater concentrations of ^{210}Pb and its decay progeny in the biosphere. Previous CNWRA calculations indicated that the continuous release of ^{222}Rn would not significantly change total dose estimates (Pensado et al., 2013).

Related gaseous releases from non-degraded waste of radon isotopes associated with the actinium and thorium decay chains are not expected to influence performance assessment results. Because ^{219}Rn, ^{220}Rn, and their respective decay progeny are so short lived (e.g., the longest-lived decay product has a half-life of 10.6 hours), these decay chains would reach their stable end points in the geosphere, which precludes radiological implications in the biosphere.

Actinium decay chain

For the actinium decay chain, SKB assumed that ^{239}Np was in secular equilibrium with its ^{243}Am parent and ^{227}Np and ^{223}Ra were in secular equilibrium with the ^{227}Ac parent (SKB, 2010a, Table 4-6). Because SKB listed ^{239}Np, ^{227}Np, and ^{223}Ra as excluded (SKB, 2010a, Table D-1), SKB should clarify how the secular equilibrium assumption was incorporated into the performance assessment. CNWRA agrees that the SKB approach to not track ^{243}Cm separately and assign its initial inventory to ^{239}Pu is justified (refer to Section 3.3.2 of this technical note for additional discussion). Based on half-life, sorption partitioning coefficient, and ingestion dose coefficient considerations, simplifications made by SKB to not include ^{231}Th and ^{211}Pb as well as other radionuclides in the actinium decay chain will not underestimate dose. CNWRA concludes that neglecting the small branching fraction to ^{215}At (0.00023%) in the actinium decay chain (Shleien et al., 1998, Table 8.10) would be inconsequential to the SKB analysis. Considering available information on radioactive half-lives and ingestion dose coefficients, CNWRA finds that the simplifications made by SKB to the actinium decay chain (SKB, 2010a, Figure D-15 and Table D-4) are reasonable for estimating dose.

3.3.2. Incorporating initial activities for excluded radionuclides

CNWRA reviewed the four shorter-lived radionuclides (^{233}Pa, ^{241}Pu, ^{243}Cm, and ^{244}Cm), whose inventories were added to their decay progeny rather than being explicitly modelled in the radioactive decay chains (SKB, 2010a, Section 3.1).

Addition of the initial ^{233}Pa activity to the ^{233}U inventory is reasonable for the following reasons. Instantaneous release and corrosion release fractions are zero for both elements (SKB, 2010a, Table 3-4). Although the values for protactinium solubility are considerably greater than those for uranium (SKB, 2010a, Table 3-4), the very short half-life of 27.0 d for ^{233}Pa compared to the much longer groundwater travel times (SKB, 2010a, Table 4-3) will more than offset temporary concentration increases of ^{233}Pa near any initially failed containers prior to radionuclide transport to the biosphere. Compared to its parent (^{237}Np) and decay product (^{233}U) in the neptunium decay chain, the potential for enhanced water concentrations of ^{233}Pa near failed canisters due to its greater solubility (SKB, 2010a, Table 3-4) is expected to be constrained by the dominating molar presence of ^{231}Pa from the actinium decay chain (SKB, 2010a, Figures D-10 and D-18 for respective molar inventories per canister of ^{233}Pa and ^{231}Pa). The best estimate value of the sorption partitioning

coefficient for protactinium is slightly higher or much higher than SKB values for the two redox states of uranium (SKB, 2010a, Table 2-4). Due to the continued production of ^{233}Pa from the decay of ^{237}Np and a sorption portioning coefficient for protactinium that is slightly higher than neptunium (SKB, 2010a, Table 2-4), the activity concentrations of groundwater reaching the biosphere would be expected to have comparable activity contributions from ^{237}Np and ^{233}Pa. Because the ingestion dose coefficient for ^{233}Pa is much smaller than that of ^{237}Np (SKB, 2010a, Table D-2), the inclusion of ^{233}Pa would not result in appreciable increases to radiological doses.

Addition of the initial ^{241}Pu activity to the ^{241}Am inventory is technically adequate for the following reasons. Values for plutonium solubility are only slightly greater than those for americium (SKB, 2010a, Table 3-4). Instantaneous release and corrosion release fractions are zero for both elements (SKB, 2010a, Table 3-4). Sorption partitioning coefficients for americium and plutonium are similar for most redox states[1] (SKB, 2010a, Table 2-4). As shown by Mohanty et al. (2002, Figure 3-9), the conversion of initial ^{241}Pu activity to ^{241}Am is complete at 300 years after spent nuclear fuel is discharged from the reactor. After 300 years, the ^{241}Pu activity attains equilibrium with the activity of ^{245}Cm, a longer-lived radionuclide with less initial activity that decays to ^{241}Pu.

Addition of the initial ^{243}Cm activity to the ^{239}Pu inventory is technically appropriate for the following reasons. The values for curium solubility are less than those for plutonium (SKB, 2010a, Table 3-4). Instantaneous release and corrosion release fractions are zero for both elements (SKB, 2010a, Table 3-4). Sorption partitioning coefficients for plutonium and curium are similar for most redox states[1] (SKB, 2010a, Table 2-4). The dose coefficient for ^{239}Pu exceeds the value for ^{243}Cm (SKB, 2010a, Table D-4). The conversion of initial ^{243}Cm activity to ^{239}Pu is complete after a few hundred years (Mohanty et al., 2002, Figure 3-9).

Addition of the initial ^{244}Cm activity to the ^{240}Pu inventory is technically adequate for the following reasons. The values for curium solubility are less than those for plutonium (SKB, 2010a, Table 3-4). Initial release and corrosion release fractions are zero for both elements (SKB, 2010a, Table 3-4). Sorption partitioning coefficients for plutonium and curium are similar for most redox states[1] (SKB, 2010a, Table 2-4). The conversion of initial ^{244}Cm activity to ^{240}Pu is complete after a few hundred years (Mohanty et al., 2002, Figure 3-9).

3.3.3. Dose coefficient selection

As indicated by Benke and LaPlante (2012, page 13), available documentation was insufficient to verify SKB statements regarding the addition of radiological dose coefficients for short-lived decay progeny to those values used for the included parent radionuclide. SKB should furnish supporting information to show which short-lived decay progeny were included in the determination of dose coefficients for the modelled radionuclides. For example, several of the decay progeny radionuclides, identified in Table 4-6 of SKB (2010a) to be in secular equilibrium with a longer-lived parent, do not have ingestion dose coefficient values tabulated in the appendix on the selection of radionuclides (SKB, 2010a, Appendix D). In

[1]Exception: The redox state IV for plutonium was assigned a best estimate value for the sorption distribution coefficient that was more than 3 times greater than the other best estimate values for plutonium, americium, and curium (SKB, 2010a, Table 2-4).

particular, dose coefficient values were not listed for ^{228}Ra, ^{228}Th, ^{224}Ra, ^{225}Ra, ^{225}Ac, ^{210}Bi, ^{210}Po, ^{227}Th, and ^{223}Ra, which calls into question if dose coefficients for these radionuclides were added to the dose coefficient values for their respective parent radionuclides. Dose coefficient values for ^{241}Pu, ^{233}Pa, ^{234}Th, ^{242}Cm, and ^{239}Np were presented in Tables D-2 to D-4, but there were no tabulations showing the addition of these dose coefficients to the individual radionuclide values for their decay parents. Additionally, separate tabulations were not found of radionuclide dose coefficients used in the SKB calculations for fission and activation products.

4. The Consultants' Overall Assessment

As part of the SSM framework agreements covering Performance Assessment and the review area on independent modelling of radionuclide transport, CNWRA supported SSM main review phase activities by reviewing the SKB selection and abstraction of radionuclides in the SR-Site safety assessment. A summary of the CNWRA assessment and remarks on future work are presented in this section.

4.1. The consultants' assessment

Compared to the sets of radionuclides assessed by other nuclear waste programs considered in this review, the SKB set of selected radionuclides is generally inclusive. Furthermore, CNWRA finds the SKB supporting rationale and calculations to be appropriate for most of the excluded radionuclides but recommends that SSM request additional information from SKB to strengthen the screening analysis in a few areas.

- SKB should provide the rationale to support the exclusion of ^{126}Sb. In particular, discussion of the sorption partitioning coefficient for ^{126}Sb would allow a comparison to values for its long-lived and highly sorbing parent radionuclide, ^{126}Sn. Refer to Section 2.3.1 for additional detail.
- SKB should supplement existing information on radionuclide screening and selection with an assessment of radionuclides deposited on cladding surfaces. Refer to Section 2.3.2 for additional detail.
- SSM may decide to ask SKB to evaluate the potential additional contributions to near-field releases of ^{210}Pb due to the escape of ^{222}Rn gas from non-degraded waste. Refer to Section 3.3.1 for additional detail.
- SKB should clarify how the secular equilibrium assumption was incorporated into the performance assessment. Refer to Section 3.3.1 for additional detail.
- Because SKB statements on the inclusion of short-lived radionuclides in the determination of radiological dose coefficients could not be verified from the available documentation, SKB should provide supporting information that identifies individual radionuclides and specifies dose coefficient values used in the safety assessment. Refer to Section 3.3.3 for additional detail.

4.2. Future work

The reviews of any additional information provided by SKB, in response to the recommendations presented in the previous subsection, are expected to be straightforward. As long as issues identified by the other main review phase activities, which conclude after the completion of this report, do not have a direct bearing on radionuclide selection and abstraction, no other areas requiring future work are anticipated.

5. References

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APPENDIX 1

Coverage of SKB reports

Main review phase activities build on the investigations performed in the initial review phase. Two initial review phase activities, documented in technical notes by Pensado and Mohanty (2012) and Benke and LaPlante (2012), are particularly relevant to the material covered in this review assignment. Coverage of SKB reports pertaining to the review of radionuclide abstraction and selection is presented in Table A1. Coverage for initial review phase activities is not repeated here.

Table A1: Review coverage of SKB reports for radionuclide abstraction and selection

Reviewed report	Reviewed sections	Comments
TR–10–50, Radionuclide transport report for the safety assessment SR-Site	Entire report	Refer to Sections 2 and 3 of this technical note
TR–10–13, Spent nuclear fuel for disposal in the KBS-3 repository	Entire report	Refer to Sections 2 and 3 of this technical note

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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.

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