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Corrected implementation of fracture model used for 1BMA and 2BMA in SR-PSU

1 Background

The degradation of the concrete barriers in 1BMA and 2BMA was found to have been implemented incorrectly in the radionuclide transport models supporting the application for the extension of SFR (SR-PSU) (SKB 2015a, b). Degradation should have been modeled through a transition from a homogenous medium model to a fractured medium model (the fractured medium is assumed for severely and completely degraded concrete in the barriers). However, the model did not calculate the process in the way described in SKB (2015b).

This text describes the effects of this error on the results from the global warming calculation case (CCM_GW) and the calculation case with accelerated concrete degradation (CCL_BC).

2 Effects on the global warming calculation case

Table 2-1shows the peak annual dose for the corrected global warming calculation case and Table 2-2 shows the corresponding results for the calculations in SR-PSU (SKB 2015b, table 5-1). The peak dose from the entire extended SFR is not affected by the modelling error, as it occurs prior to the transition to severely degraded concrete. The error has a small, insignificant impact on the peak dose from 1BMA. However, the timing and the size of the peak dose from 2BMA are affected. The information in Table 2-1 and Table 2-2 is further described in SKB (2015b, Chapter 5).

Figure 2-1 shows the doses arising from 2BMA over time. These are higher than calculated in SR-PSU (Figure 2-1) for the time period following severe barrier degradation (22 000 AD), reflecting increased radionuclide transport from 2BMA with the correct implementation of the model.

Table 2-1. Peak annual doses and the time at which the peak is observed for releases from 1BMA, 2BMA and from the entire extended repository in the corrected *global warming calculation case*. The radionuclides with the highest contribution to the peak are indicated.

Waste vault	Annual dose [μSv]	Year [AD]	Biosphere object	Exposed group	Most contributing radionuclide (%)
1BMA	1.82	66,500	157_2	DM	Ni-59 (65.9)
2BMA	1.06	28,500	157_1	DM	Ca-41 (57.0)
Total SFR	7.69	6500	157_2	DM	Mo-93 (57.7)

Table 2-2. Peak annual doses and the time at which the peak is observed for releases from 1BMA, 2BMA and from the entire extended repository in the *global warming calculation case, as calculated in SR-PSU*. The radionuclides with the highest contribution to the peak are indicated.

Waste vault	Annual dose [μSv]	Year [AD]	Biosphere object	Exposed group	Most contributing radionuclide (%)
1BMA	1.77	66,500	157_2	DM	Ni-59 (65.4)
2BMA	0.88	10,500	157_2	DM	Mo-93 (68.8)
Total SFR	7.69	6500	157_2	DM	Mo-93 (57.7)

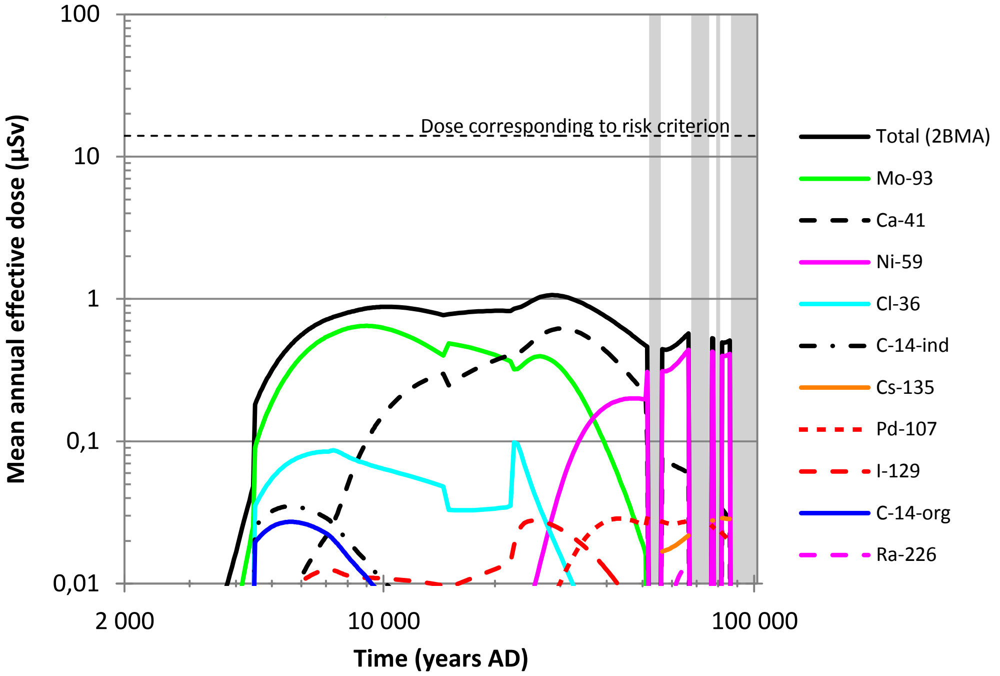

***Figure 2-1.** Arithmetic mean of the annual dose to the most exposed group for releases from **2BMA** in the **corrected global warming calculation case**. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost.*

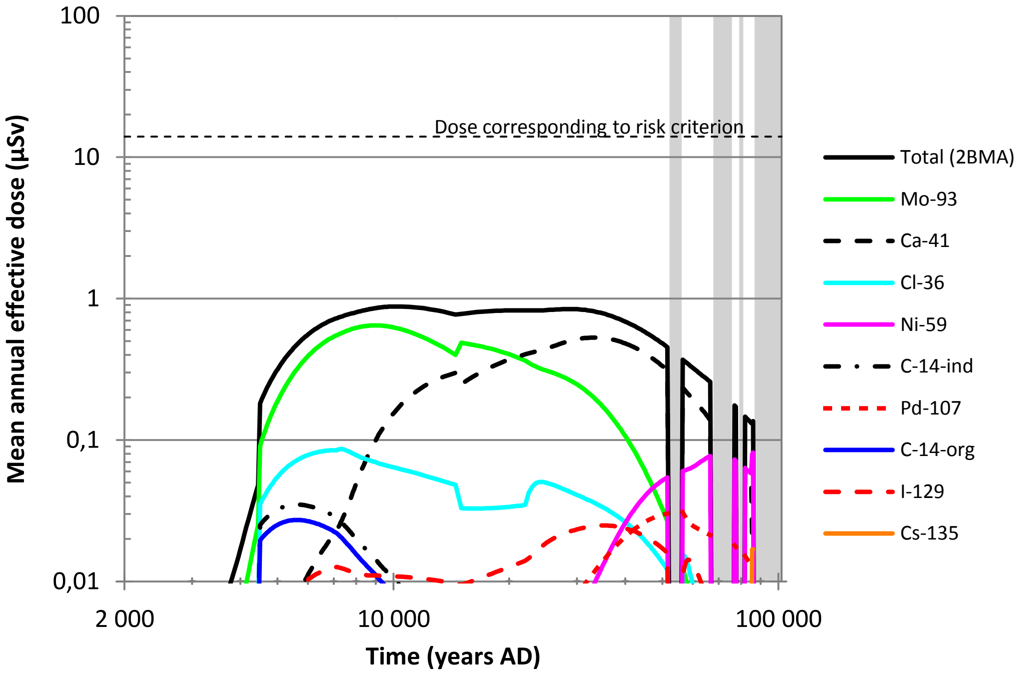

***Figure 2-2.** Arithmetic mean of the annual dose to the most exposed group for releases from **2BMA** in the **global warming calculation case**, **as calculated in SR-PSU**. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost.*

Figure 2-3 Figure 2-3 shows the total dose for the entire extended SFR over time in the global warming calculation case with the corrected model. The total dose calculated in SR-PSU is also shown. Comparison of the dotted red curve (from SR-PSU) and the black curve (calculations with the corrected model) shows that the results are unaffected by the error up to 22,000 AD, after which there is a small, insignificant effect.

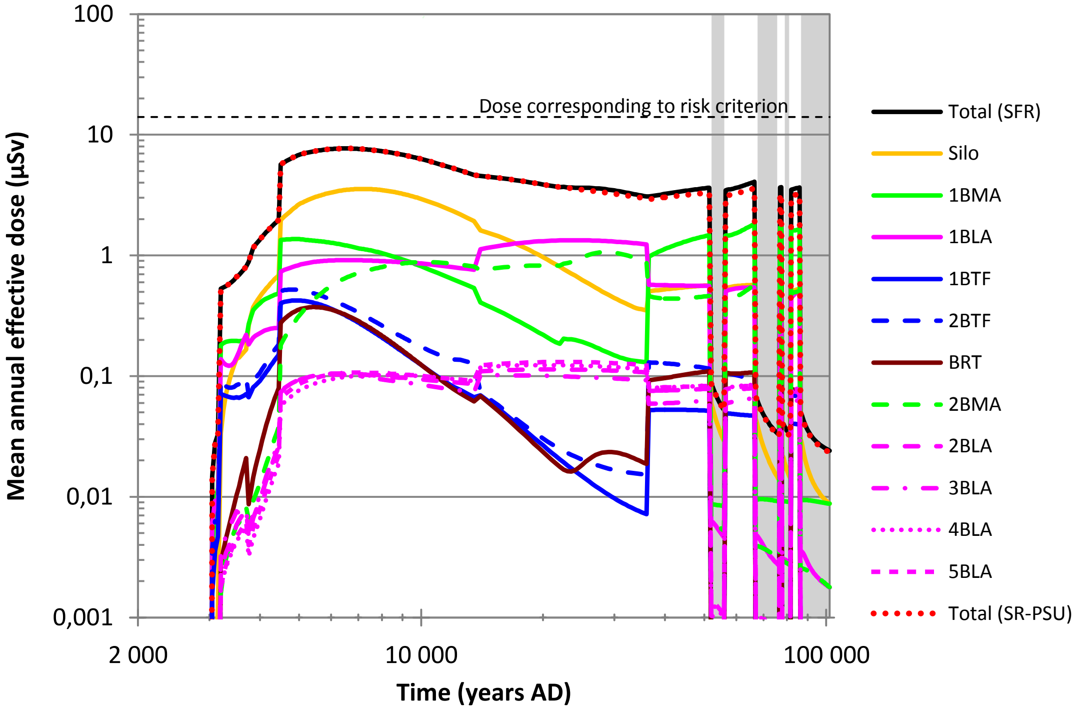

Figure 2-3. *Arithmetic mean of the annual effective dose to the most exposed group, for releases from the entire extended repository and contributions from the individual waste vaults, in the* ***corrected global warming calculation case****. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost.* ***The dotted red line shows the result as calculated in SR-PSU.***

3 Effects on the calculation case with accelerated concrete degradation

When the modelling error had been corrected for in the calculation case with accelerated concrete degradation, the total dose increased from 10.6 µSv (in SR-PSU) to 15.8 µSv (Table 3-1). The main contribution to this increase comes from 2BMA, which after the correction makes the largest contribution to the peak dose, 37.8%. In the calculation in SR-PSU, 2BMA contributed only 8.8% of the peak dose (Table 3-2).

Table 3-1. Peak annual dose (and related data) to a representative individual of the most exposed group obtained for the corrected *accelerated concrete degradation calculation case*.

Annual dose [µSv]	Year [AD]	Contribution from waste vault (%)	Contribution from radionuclide (%)
15.8	5450	2BMA (37.8)	Mo-93 (70.7)
		1BMA (23.7)	C-14-org (12.0)
		Silo (22.3)	I-129 (4.5)
		1BLA (5.6)	Cl-36 (3.1)
		2BTF (3.3)	U-238 (2.9)
		1BTF (2.6)	Ca-41 (2.1)
		BRT (2.4)	C-14-inorg (1.7)
		2-5BLA (2.3)	Others (3.2)

Table 3-2. Peak annual dose (and related data) to a representative individual of the most exposed group obtained for the *accelerated concrete degradation calculation case*, as calculated in SR-PSU.

Annual dose [µSv]	Year [AD]	Contribution from waste vault (%)	Contribution from radionuclide (%)
10.6	5550	1BMA (33.6)	Mo-93 (59.8)
		Silo (33.6)	C-14-org (17.0)
		2BMA (8.8)	I-129 (6.4)
		1BLA (8.4)	U-238 (4.3)
		2BTF (4.8)	Cl-36 (4.0)
		1BTF (3.8)	C-14-inorg (2.3)
		BRT (3.5)	U-235 (1.8)
		2-5BLA (3.7)	Others (4.4)

Table 3-3shows the peak doses from 1BMA, 2BMA and the whole extended SFR, calculated with the corrected model. Table 3-4 shows the corresponding values from the calculation in SR-PSU. There is only a small difference in the results for 1BMA while the difference for 2BMA is larger and leads to an increase in the total dose for the whole extended SFR.

The calculation case with accelerated concrete degradation was assigned a probability to occur of less than 10% in SR-PSU (SKB 2015a, Chapter 10), which reduces the impact of the modelling error on the overall risk. The estimated maximum risk in SR-PSU was $9.0 \cdot 10^{-7}$ at 5 000 AD and the maximum risk from the accelerated concrete degradation scenario was $7.8 \cdot 10^{-8}$ at 5 550 AD (SKB 2015a). As the doses in the accelerated concrete degradation calculation case increase by about 50% with the corrected model, the additional risk will be about $4 \cdot 10^{-8}$. The total risk for the whole assessment can therefore be expected to increase to about $9.4 \cdot 10^{-7}$ with the corrected model. Although *scenario combination 1* (SKB 2015a) includes accelerated concrete degradation, the risk from this scenario is only $1.1 \cdot 10^{-8}$ and thus an expected 50% increase in the doses in this scenario will only contribute $5.5 \cdot 10^{-9}$ to the total risk.

Table 3-3 Peak annual doses and the time at which the peak is observed for releases from 1BMA, 2BMA and from the entire extended repository in the corrected *accelerated concrete degradation calculation case*. The radionuclides with the highest contribution to the peak are indicated.

Waste vault	Annual dose [µSv]	Year [AD]	Biosphere object	Exposed group	Most contributing radionuclide (%)
1BMA	4.3	4750	157_2	DM	Mo-93 (47.5)
2BMA	6.0	5700	157_2	DM	Mo-93 (87.5)
Total SFR	15.8	5450	157_2	DM	Mo-93 (70.7)

Table 3-4 Peak annual doses and the time at which the peak is observed for releases from 1BMA, 2BMA and from the entire extended repository in the *accelerated concrete degradation calculation case,* as calculated in SR-PSU. The radionuclides with the highest contribution to the peak are indicated.

Waste vault	Annual dose [µSv]	Year [AD]	Biosphere object	Exposed group	Most contributing radionuclide (%)
1BMA	4.2	4800	157_2	DM	Mo-93 (47.7)
2BMA	1.6	9350	157_2	DM	Mo-93 (75.6)
Total SFR	10.6	5550	157_2	DM	Mo-93 (59.8)

Figure 3-1 and figure 3-2 show the development of the doses from 2BMA over time in the corrected and original calculations respectively.

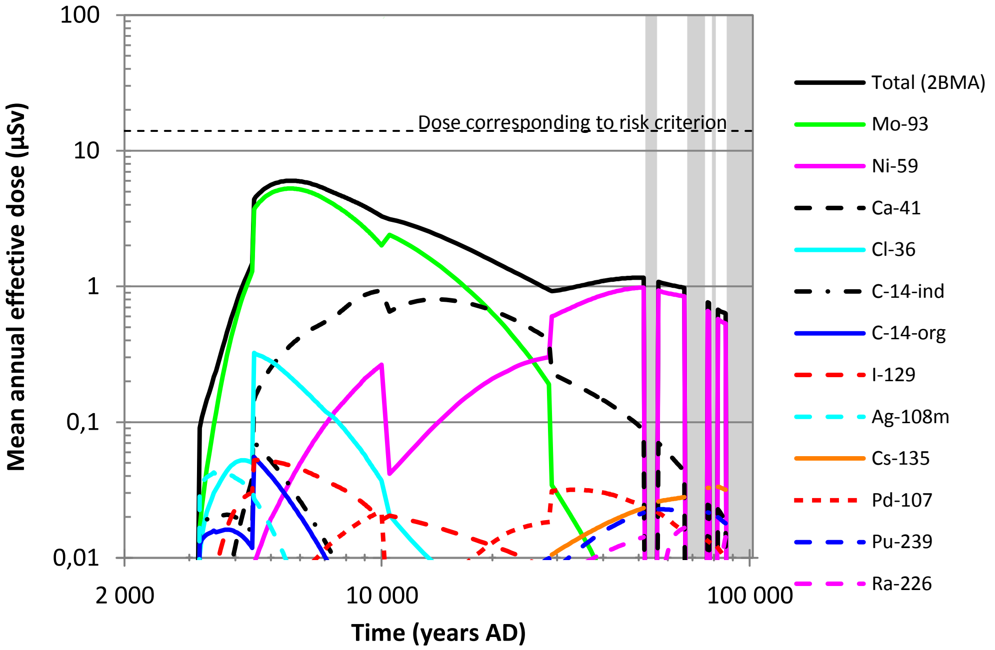

Figure 3-1. *Arithmetic mean of the annual dose to the most exposed group, shown for releases from* ***2BMA*** *in the* ***corrected accelerated concrete degradation calculation case****. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost.*

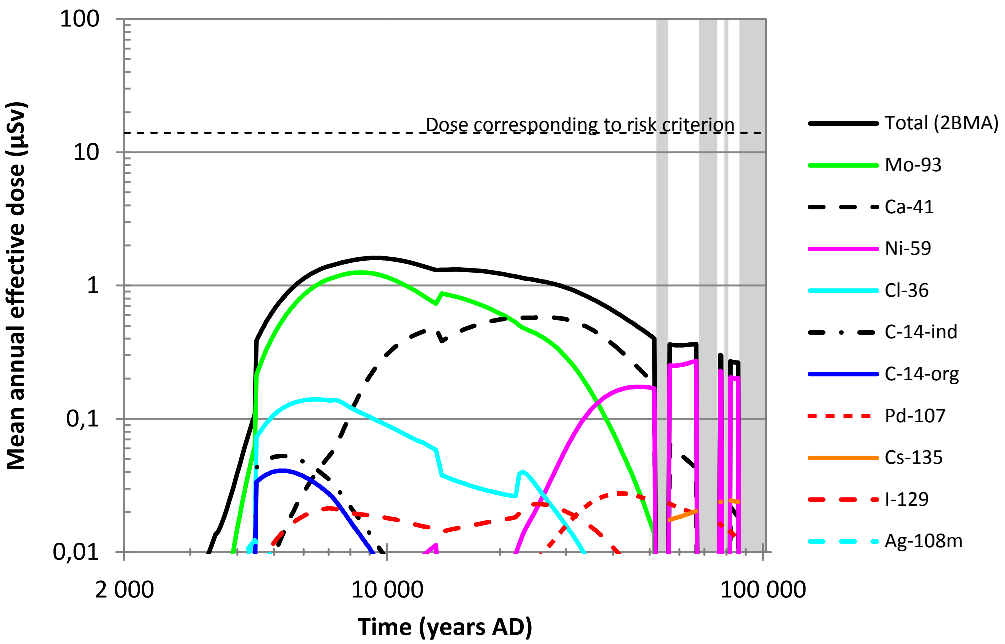

***Figure 3-2.** Arithmetic mean of the annual dose to the most exposed group, shown for releases from **2BMA** in the **accelerated concrete degradation calculation case, as calculated in SR-PSU**. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost.*

Figure 3-3 shows the total dose for SFR in the accelerated concrete degradation calculation case using the corrected model. The total dose calculated in SR-PSU is also shown. There is a difference between the dotted red curve (from SR-PSU) and the black curve (from the calculation with the corrected model). The difference is greatest at the time of the peak dose, when the dose from the corrected model is about 50% higher than that in SR-PSU. Note that the line marked “Dose corresponding to risk criterion” is valid only for a single scenario which has 100% probability to occur. As the *accelerated concrete degradation* scenario is considered to have only 10% probability to occur the doses are well below acceptable levels. However, to estimate the total risk all scenarios must be taken into account, this risk calculation is explained in more detail in SKB (2015a, Chapter 10).

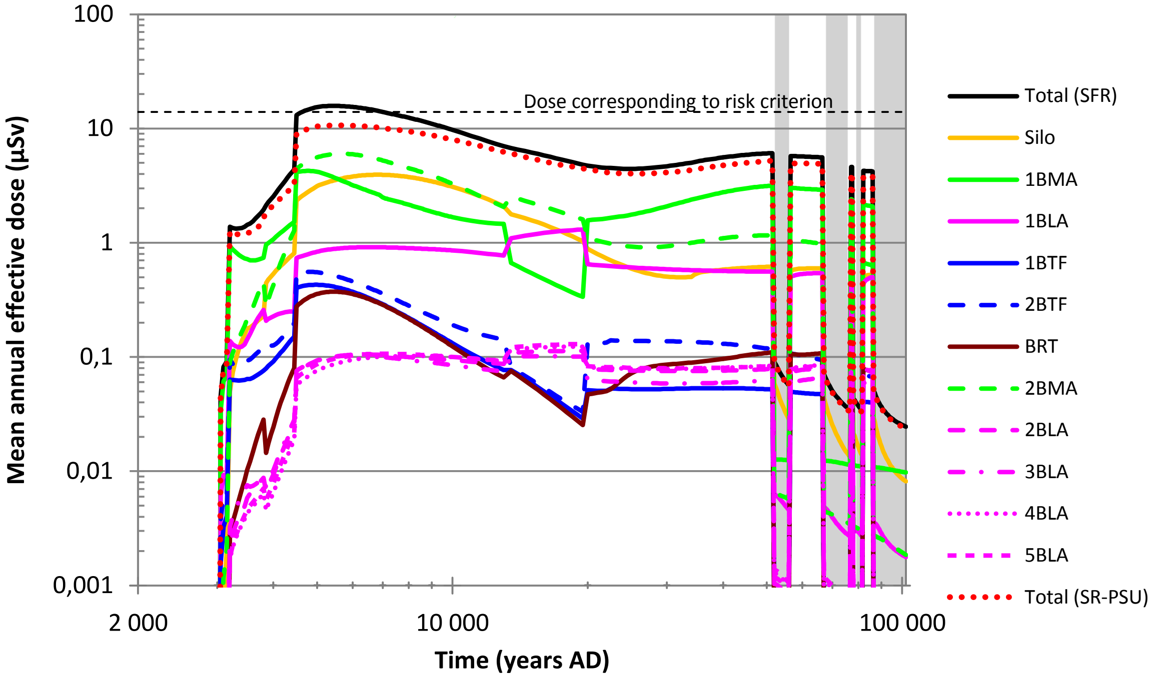

Figure 3-3.** Arithmetic mean of the annual effective dose to the most exposed group, for releases from the entire repository and contributions from the individual waste vaults, in the **corrected accelerated concrete degradation calculation case**. The unshaded areas correspond to temperate climatic conditions and the grey shaded areas to periglacial conditions with continuous permafrost. **The dotted red line shows the result as calculated in SR-PSU.

4 Conclusions

The error in the implementation of the fractured medium model affects the calculated radionuclide releases from 2BMA in the global warming calculation case during time periods when severely (or completely) degraded concrete barriers are considered. However, as the highest doses in SR-PSU were obtained before severe barrier degradation occur, the calculations with the corrected model do not affect the conclusions from SR-PSU regarding compliance with regulatory criteria.

The total risk calculated for SFR will increase slightly, mainly due to the effect of the correction of the error on the accelerated concrete degradation calculation case. The additional risk from a ~50% increase in the peak dose in the accelerated concrete degradation scenario will be about $4 \cdot 10^{-8}$ and hence the total risk increase to about $9.4 \cdot 10^{-7}$ with the updated model.

References

SKB, 2015a. Safety analysis for SFR. Long-term safety. Main report for the safety assessment SR-PSU. Revised edition. SKB TR-14-01, Svensk Kärnbränslehantering AB.

SKB, 2015b. Radionuclide transport and dose calculations for the safety assessment SR-PSU. Revised edition. SKB TR-14-09, Svensk Kärnbränslehantering AB.