sck cen
Belgian Nuclear Research Centre

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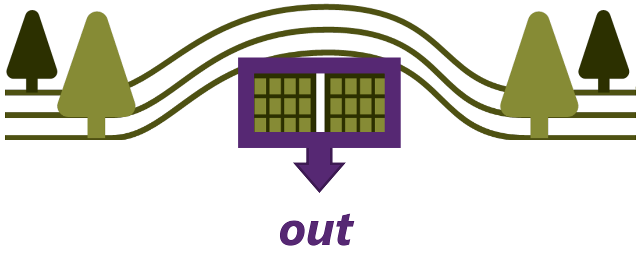
Performance Analysis of the *containment* capacity

Performance Analysis

Safety Assessment

→ *SC1 (2019)*

IMPACT ANALYSIS

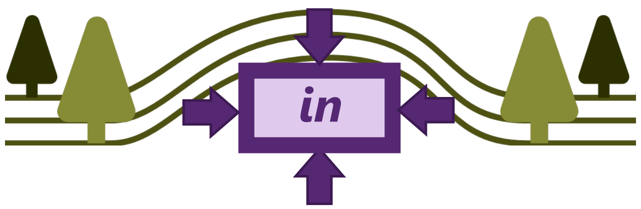


goal	Radiological impact acceptable?		
safety indicators	**Dose**	≤ 0.1 mSv/a ~3 mSv(/a)	RS HIS/PS
	Risk	≤ 10^{-5} a^{-1} ~ 10^{-6} a^{-1}	AES (all) AES (ind)
approach	conservative (no underestimation)		

→ *SC2 (2023)*

PERFORMANCE ANALYSIS

containment

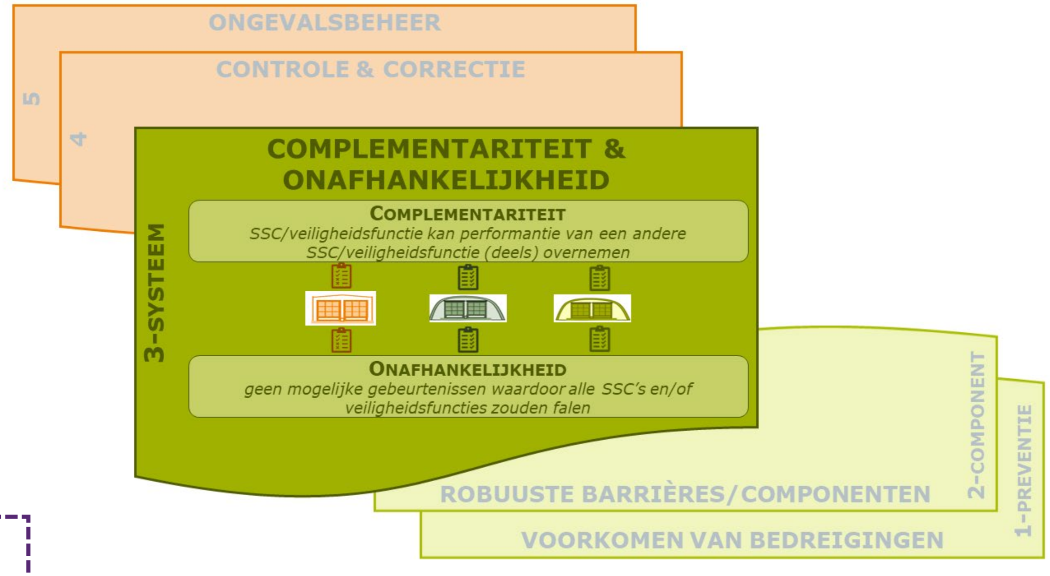


goal	Safety concept effective (DID)?		
performance indicators a.o.	**Mass-type**	**PI1** **PI2** **PI3**	% decay Act/RT in component Concentration distribution
	Flux-type	**PI4** **PI5** **PI6**	Act/RT flux between comp's RT flux out cumulative RT flux out
approach	representative (best estimate)		

Performance Analysis: *containment*

objectives

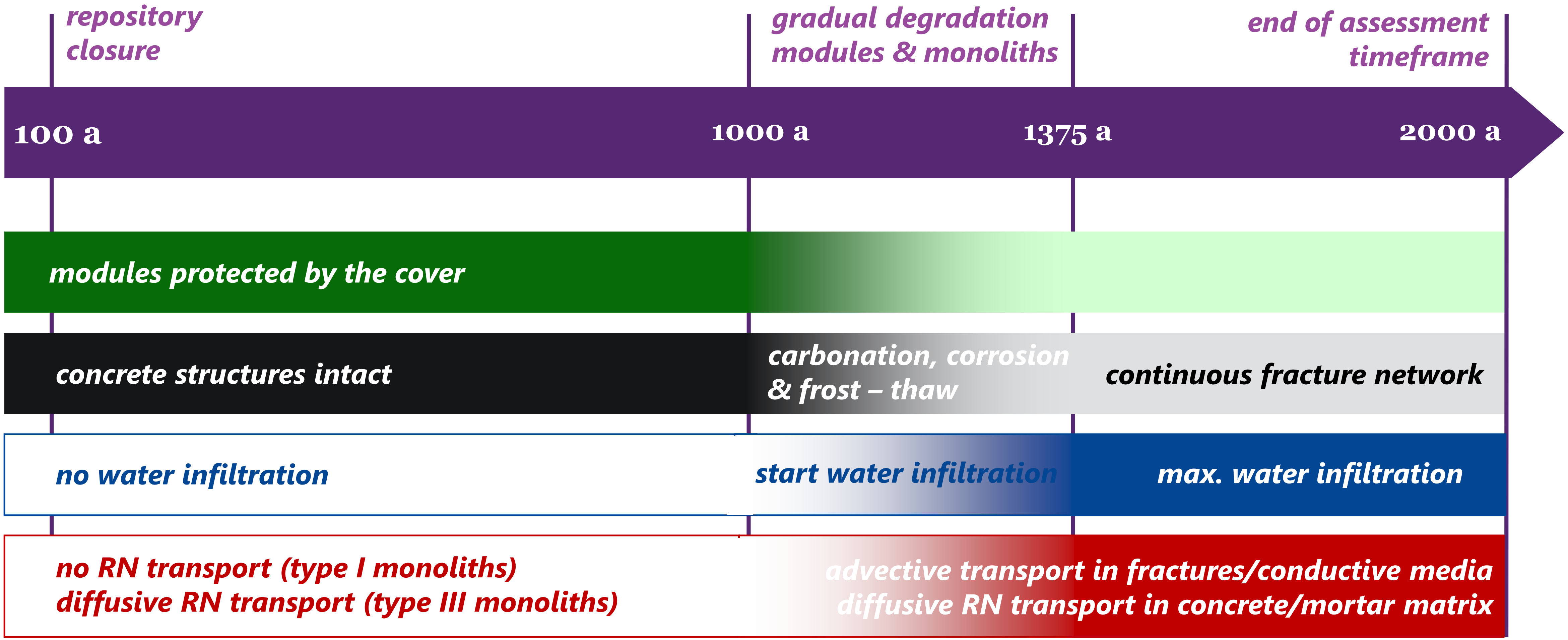
1. Quantify the ***expected containment performance*** of the disposal system and of its components and safety functions
2. Demonstrate that the disposal system and its components are ***robust*** against possible threats/perturbations
3. Demonstrate that the containment performance is ***commensurate with the risks*** posed by the waste



defence-in-depth principle

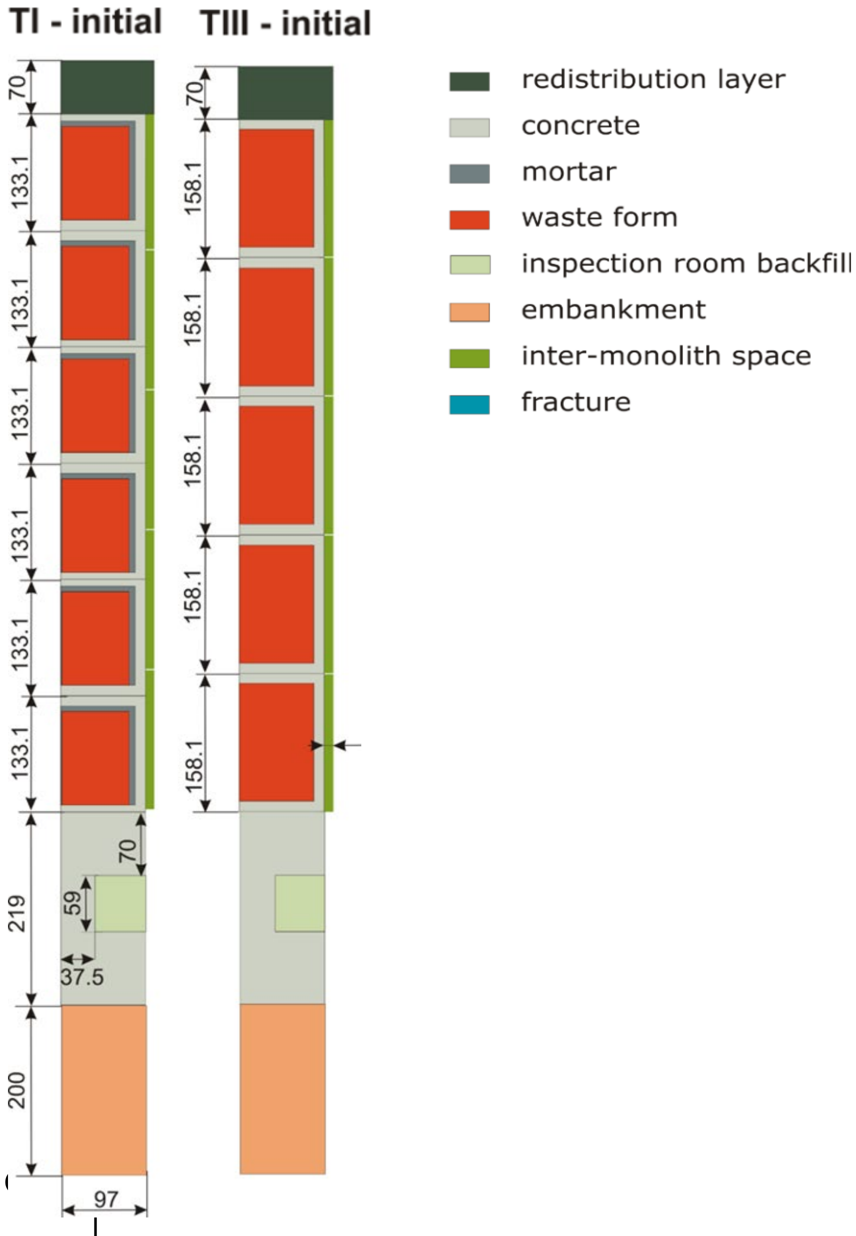
Expected performance

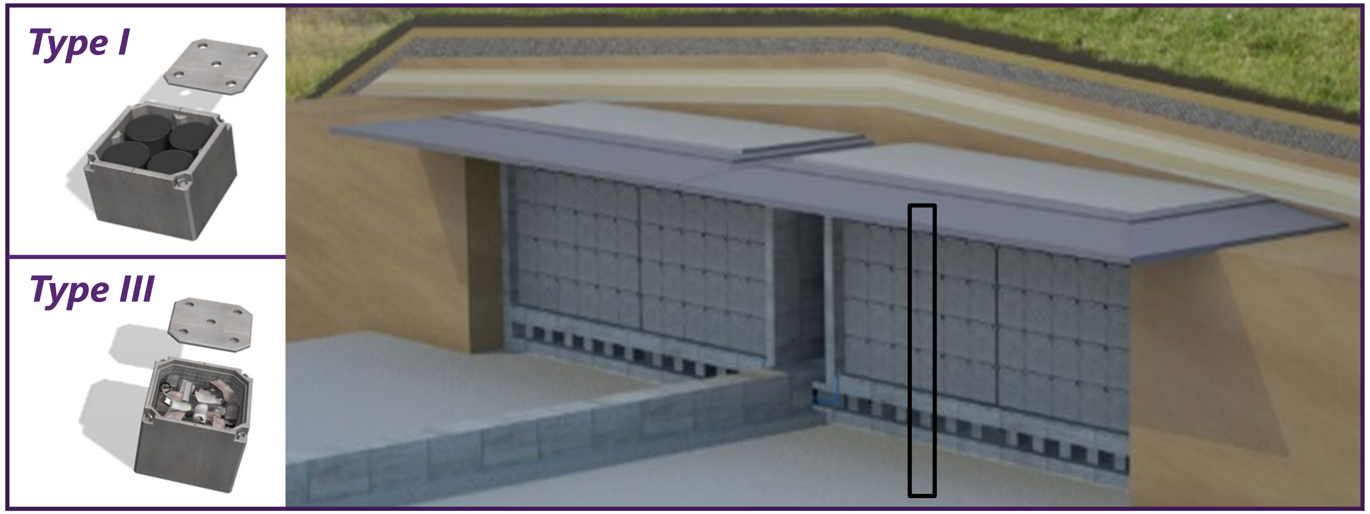
Expected evolution: EES

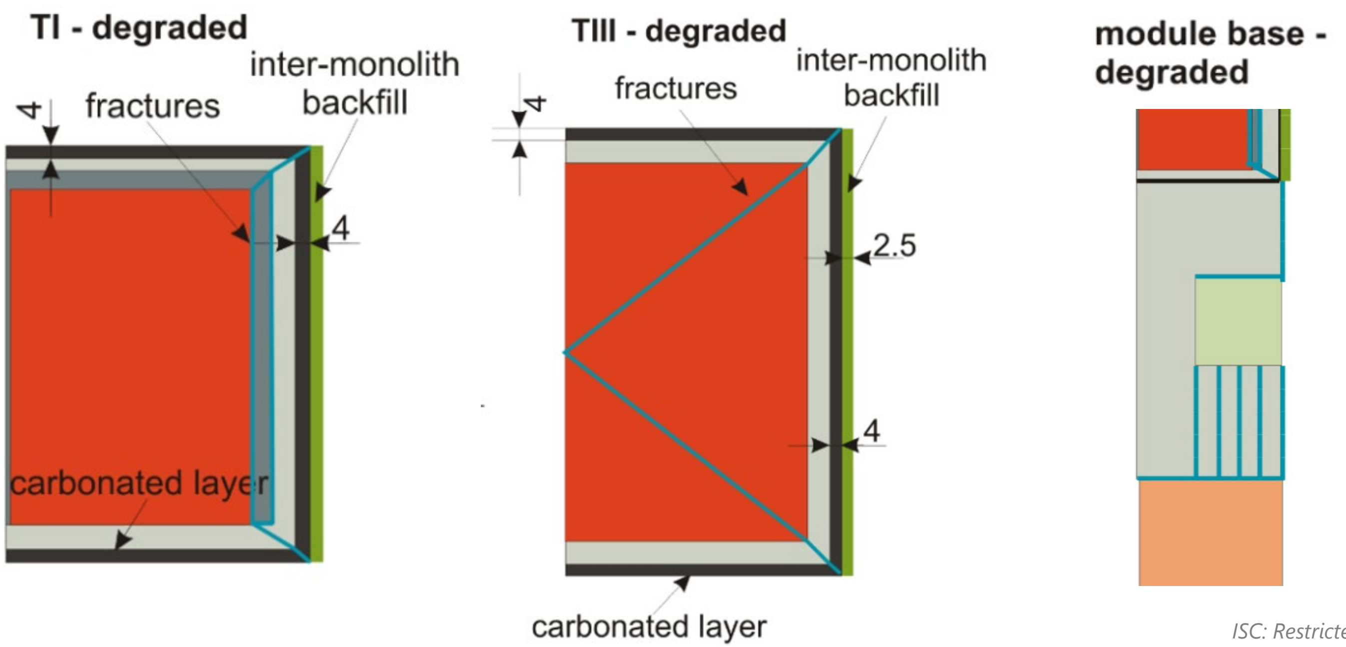



earth cover
cover
impervious top slab
(sand) side embankment
monoliths
module
Inspection room
Inspection gallery
Foundations (incl. sand-cement embankment)

Performance Analysis model







Performance indicators / output

Indicators

- ***PI1***: decayed fraction in component
- ***PI2***: activity/radiotoxicity in component
- ***PI3***: concentration profiles
- ***PI4***: flux between components
- ***PI5***: flux out of disposal system
- ***PI6***: cumulative flux out of disposal system
- ***PI7***: residence time in component / containment factor

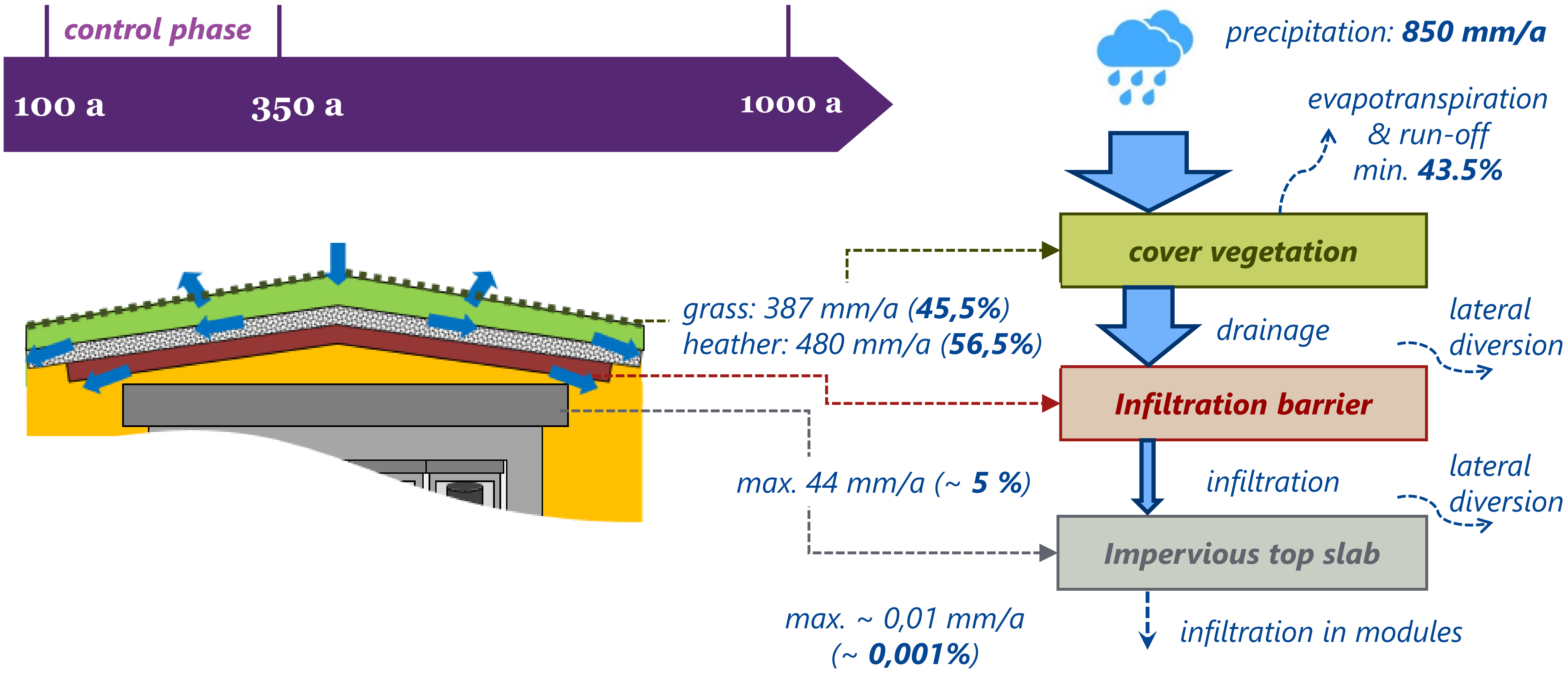
Activity distribution

- 100% in Type I monoliths
- 100% in Type III monoliths
- Weighted: 76% in Type I
24% in Type III

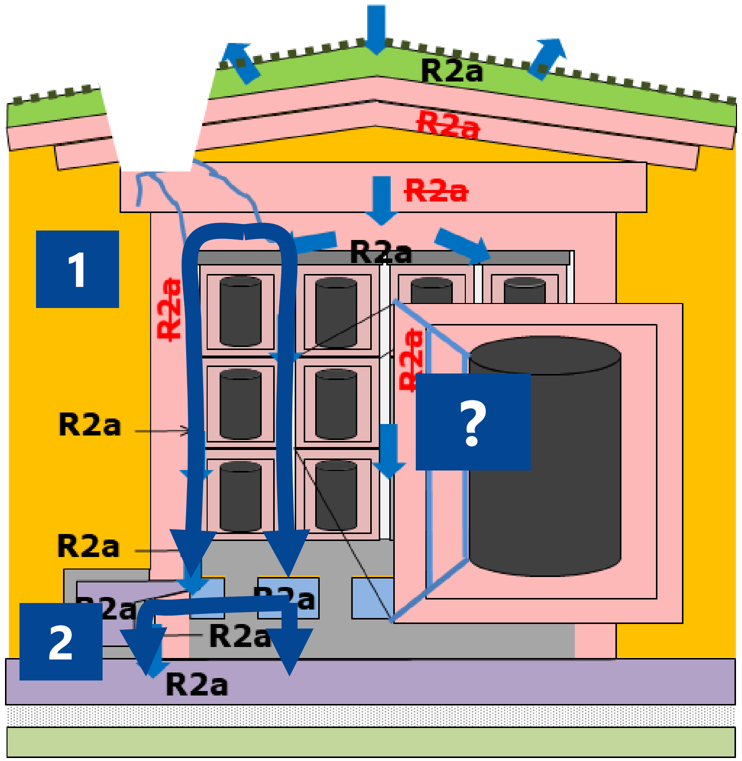
Sorption classes (on HCP)

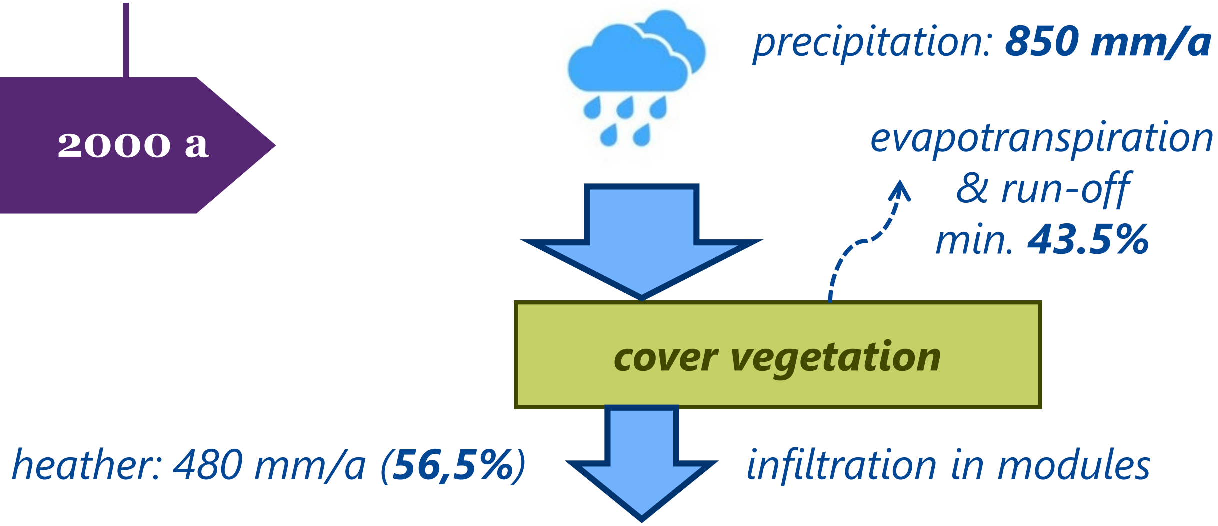
- Class I: $K_d \leq 10^{-2}$ m³/kg (e.g. Be, I, Cs)
- Class II: K_d in between (e.g. Ca, Cl, Ni)
- Class III: $K_d \geq 1$ m³/kg (e.g. Nb, Pd, act)

Limitation of water infiltration in modules (R2a)

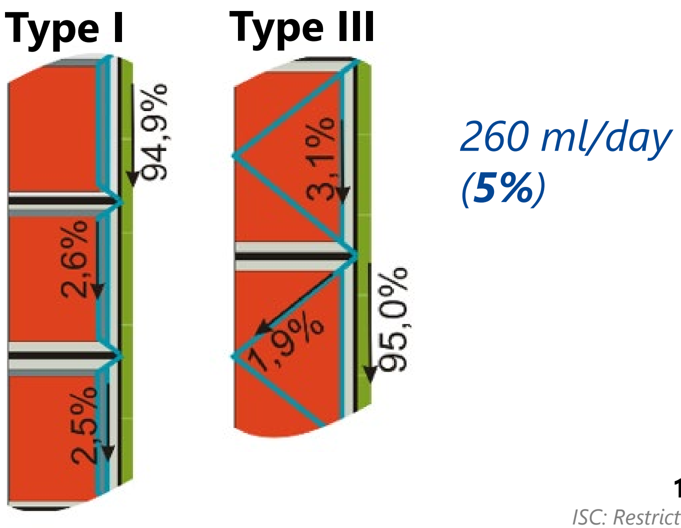


Diversion of water away from the waste (R2a)

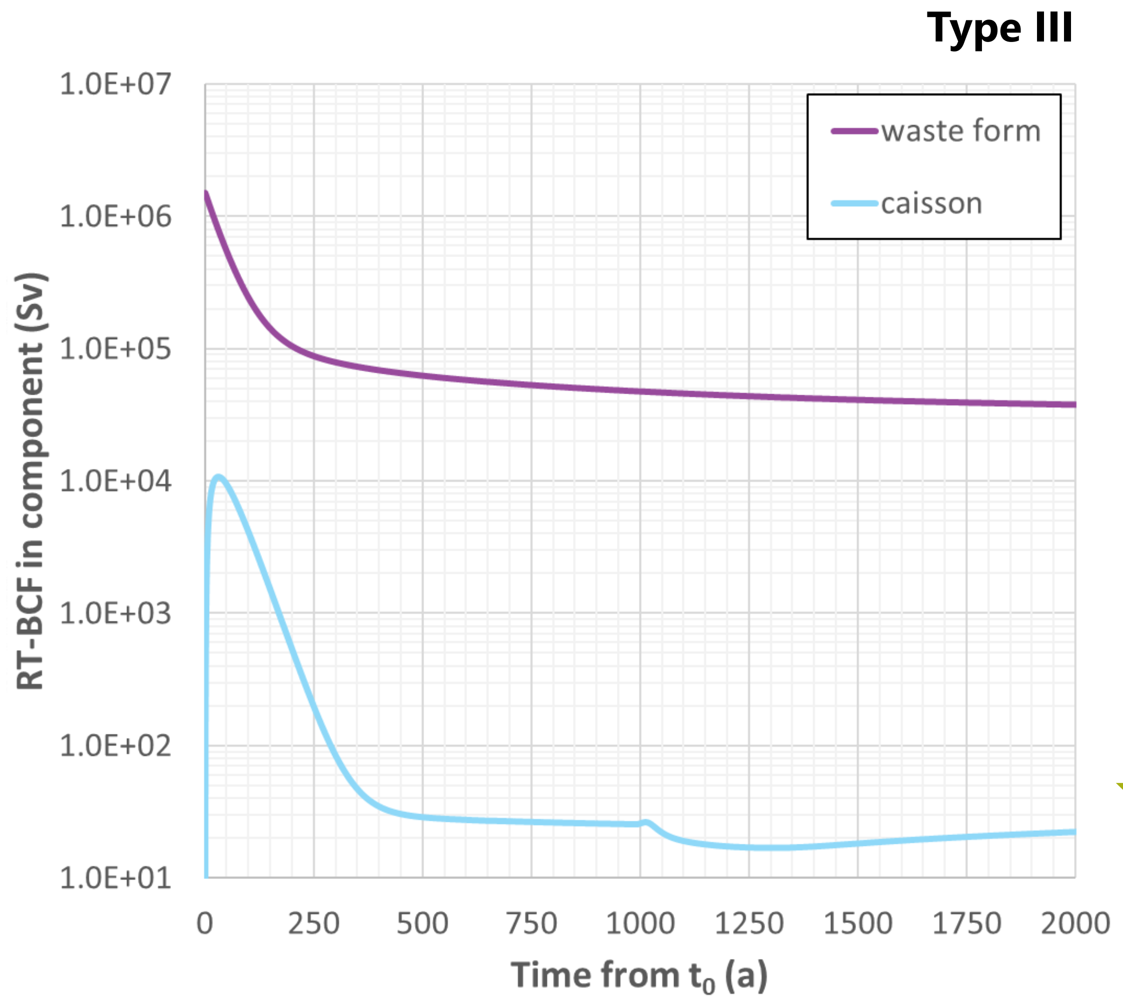




1. Preferential flow between monoliths
2. Avoid bath-tubbing by proper drainage in module base



Containment *inside* monoliths (R1/R3/R4a)

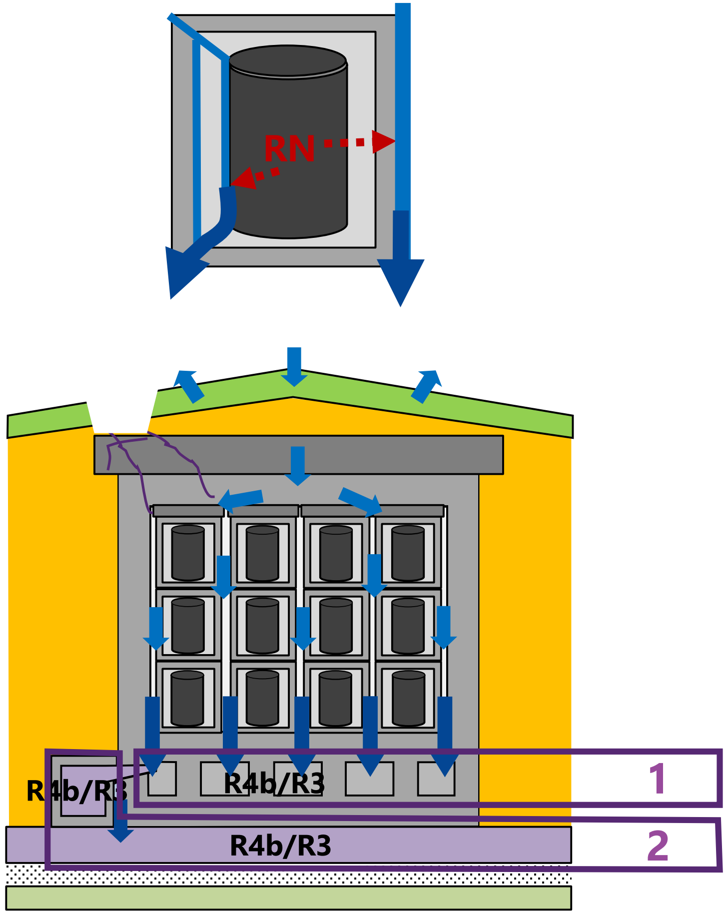


SORPTION

Activity in monolith after 2000 a

	% decay	waste	mortar	caisson	total
^{10}Be	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%
^{129}I	<0.01%	2.9%	1.1%	0.3%	4.2%
^{59}Ni	1.8%	74.0%	12.0%	2.5%	90.3%
^{239}Pu	5.6%	92.9%	1.4%	0.1%	~100%

Containment *outside* monoliths (R3/R4b)

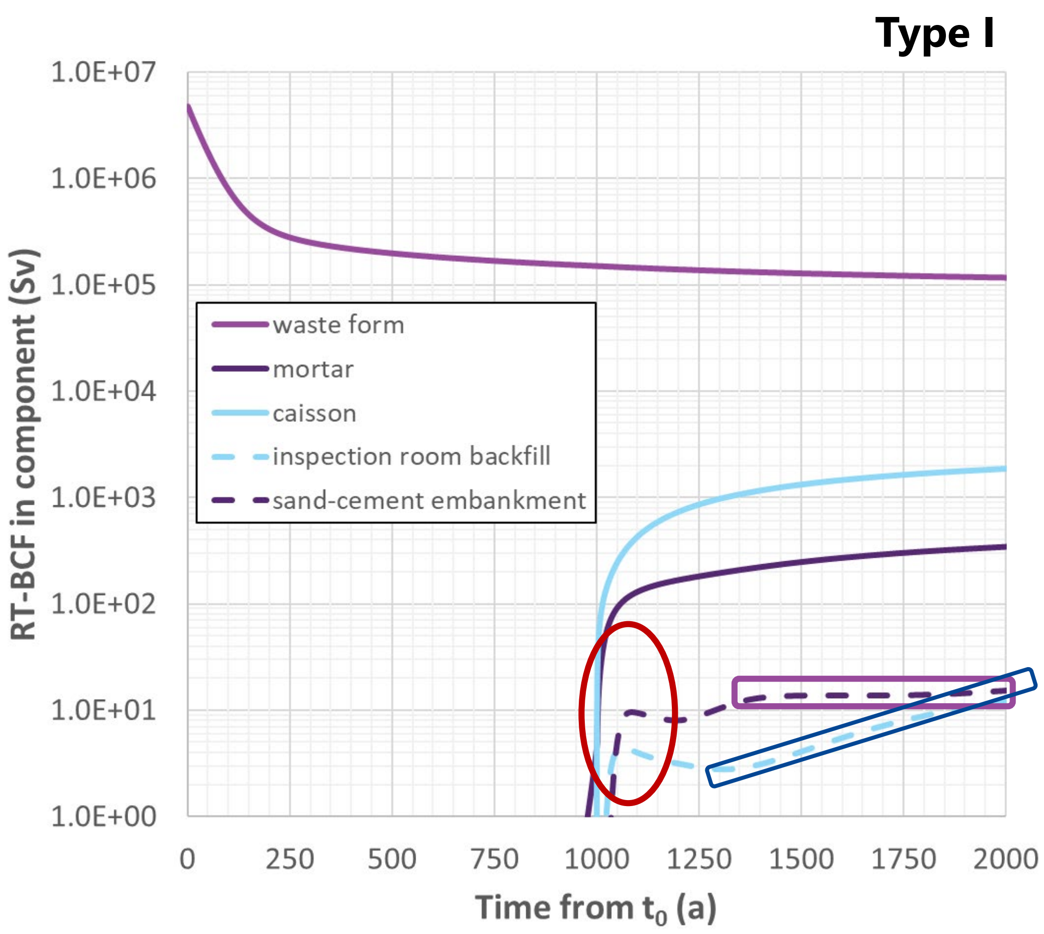


- Radionuclides that end up in fractures or the inter-monolith space (IMS) are further transported by advection

- Releases from the disposal system are still spread in time by dispersion in ***Conductive Sorbing Media (CSM):***
  1. Grout backfill in inspection room
  2. Sand-cement in embankment, inspection gallery and connecting tunnels

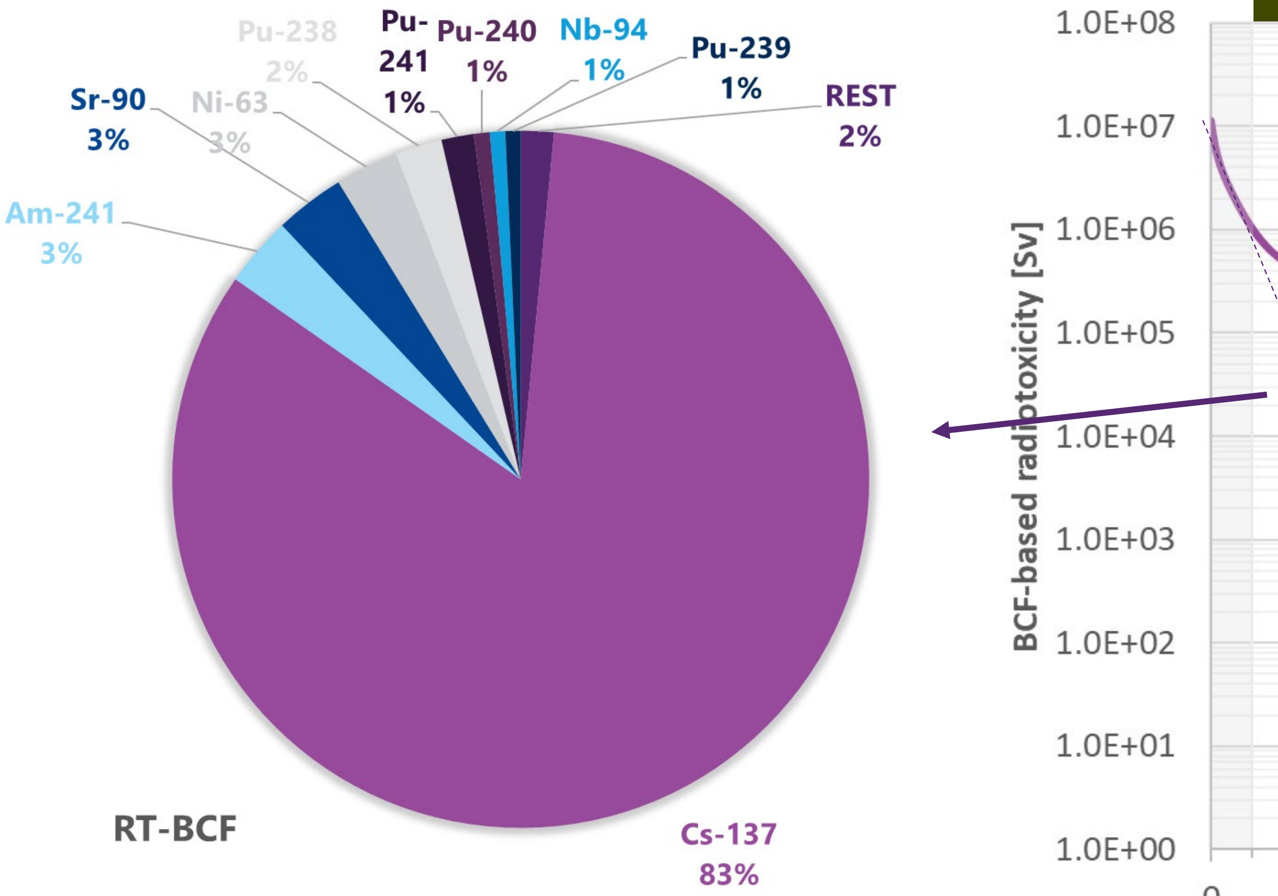
Containment *outside* monoliths (R3/R4b)

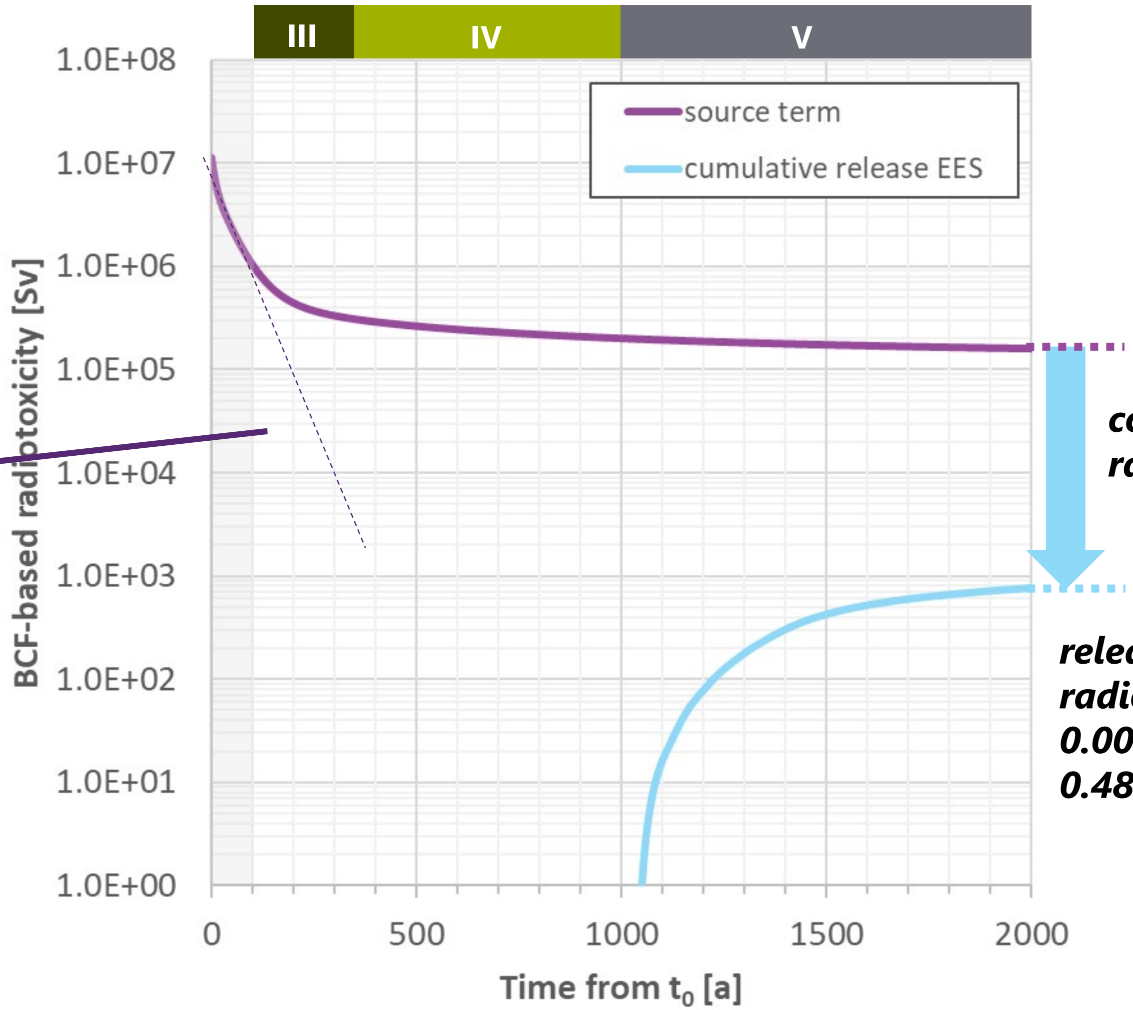
Role of conductive sorbing media



- Non-sorbed radionuclides shortly accumulate in CSM and are soon released again
- Moderately sorbed radionuclides are delayed, but reach a plateau (supply ≈ discharge)
- Well-sorbed radionuclides accumulate in the inspection room

Expected containment performance





contained radiotoxicity

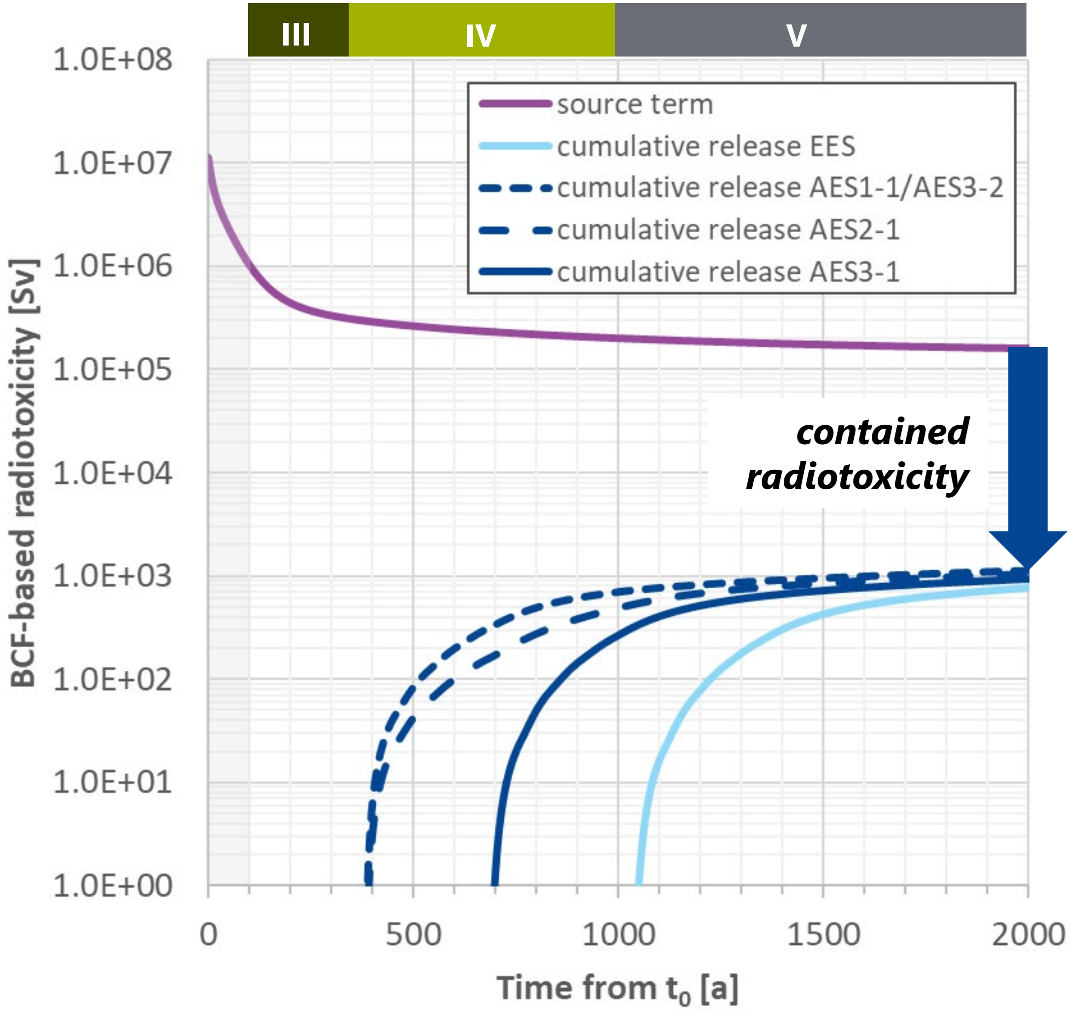
released radiotoxicity 0.0068% of initial 0.48% of residual

Robustness

Robustness against *threats*

1	Threats directly compromising the *protective* role of the earth *cover*	• Erosion **(AES3-1, AES3-2)** • Crash of small aircraft **(AES2-1)** • Earthquake **(AES1-1)**	• Early gradual degradation
2	Threats causing a direct and *abrupt* degradation of cementitious SSCs	• Crash of a large aircraft **(AES2-2)** • Heavy earthquake **(AES1-2)** • Large scale excavation **(HIS excav)**	• Early abrupt degradation • 50% water flow in monolith fractures • Extra fracture in Type I monoliths
3	Threats causing a *bypass* of SSCs that normally contribute to the containment capacity	• Borehole drilling **(HIS drill)**	• Bypass of CSM (all monoliths in affected module) • Same as 2 (pierced stack)
4	Threats causing *internal* perturbations	• undetected complexants in the waste form **(AES4)**	• 1% of the waste with zero sorption

Impairment of the cover

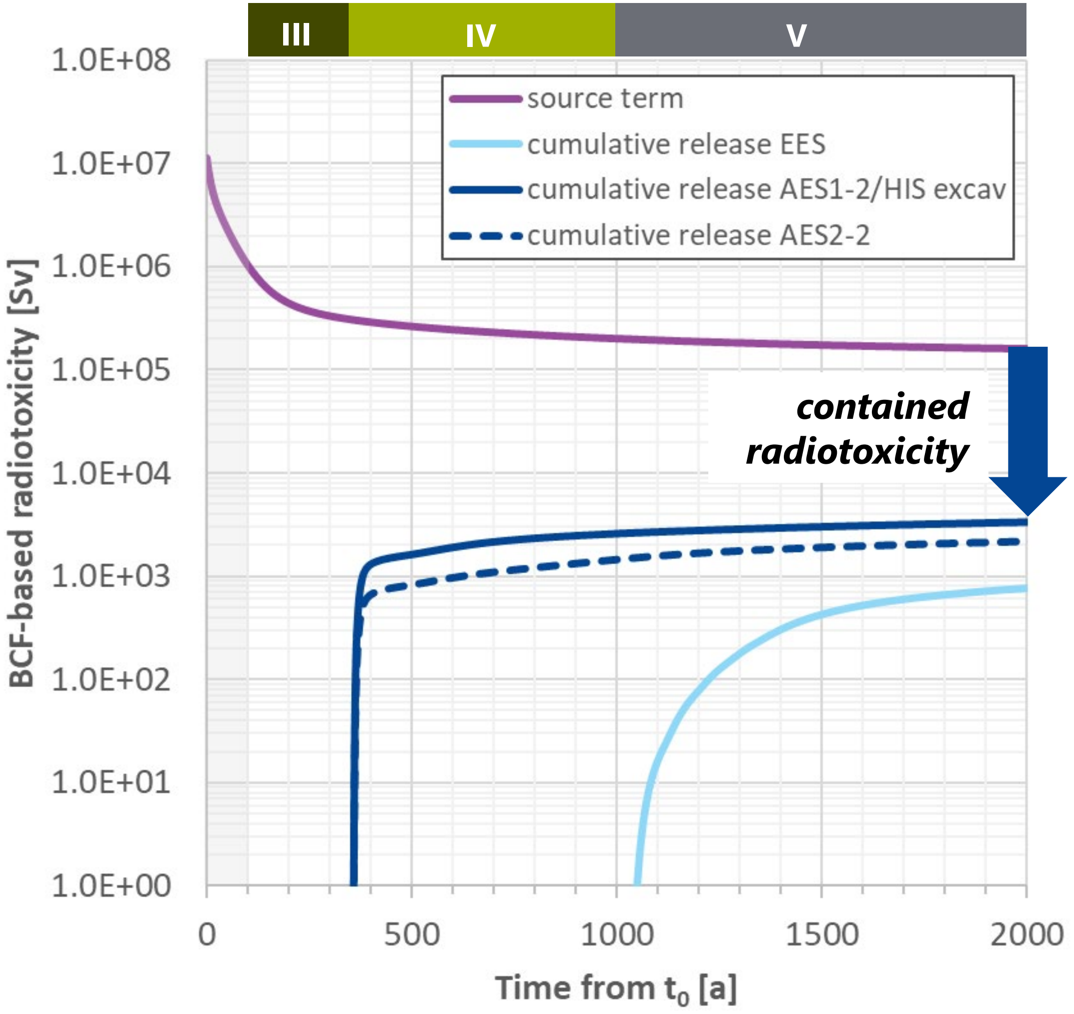


Cumulative released RT	EES	AES1-1	AES2-1	AES3-1
% of initial RT	0.0068	0.0102	0.0093	0.0084
% residual RT	0.48	0.72	0.65	0.59

Performance loss of the cover is compensated by:

- Efficient water diversion away from the waste (R2a)
- Slow release from the waste form (R1/R3)
- Dispersion in conductive sorbing media (R4b/R3)

Abrupt and extreme degradations



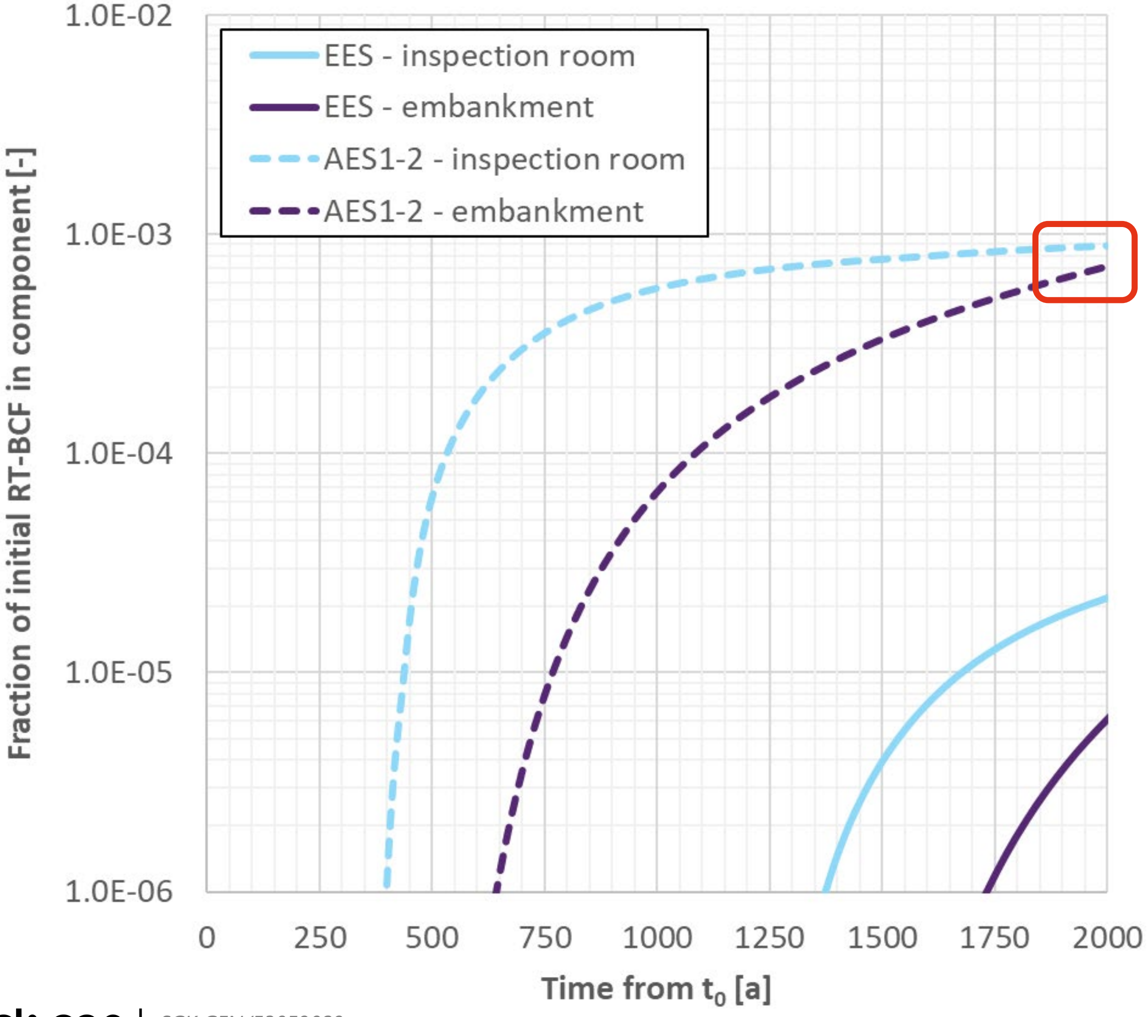
Cumulative released RT	EES	AES1-2	AES2-2	HIS excav
% of initial RT	0.0068	0.0302	0.0193	0.0302
% residual RT	0.48	2.13	1.36	2.13

Performance loss of cementitious barriers is compensated by:

- Slow release from the waste form (R1/R3)
- Dispersion in conductive sorbing media (R4b/R3)

Role of conductive sorbing media (bis)

Sorption class III nuclides in Type I monoliths

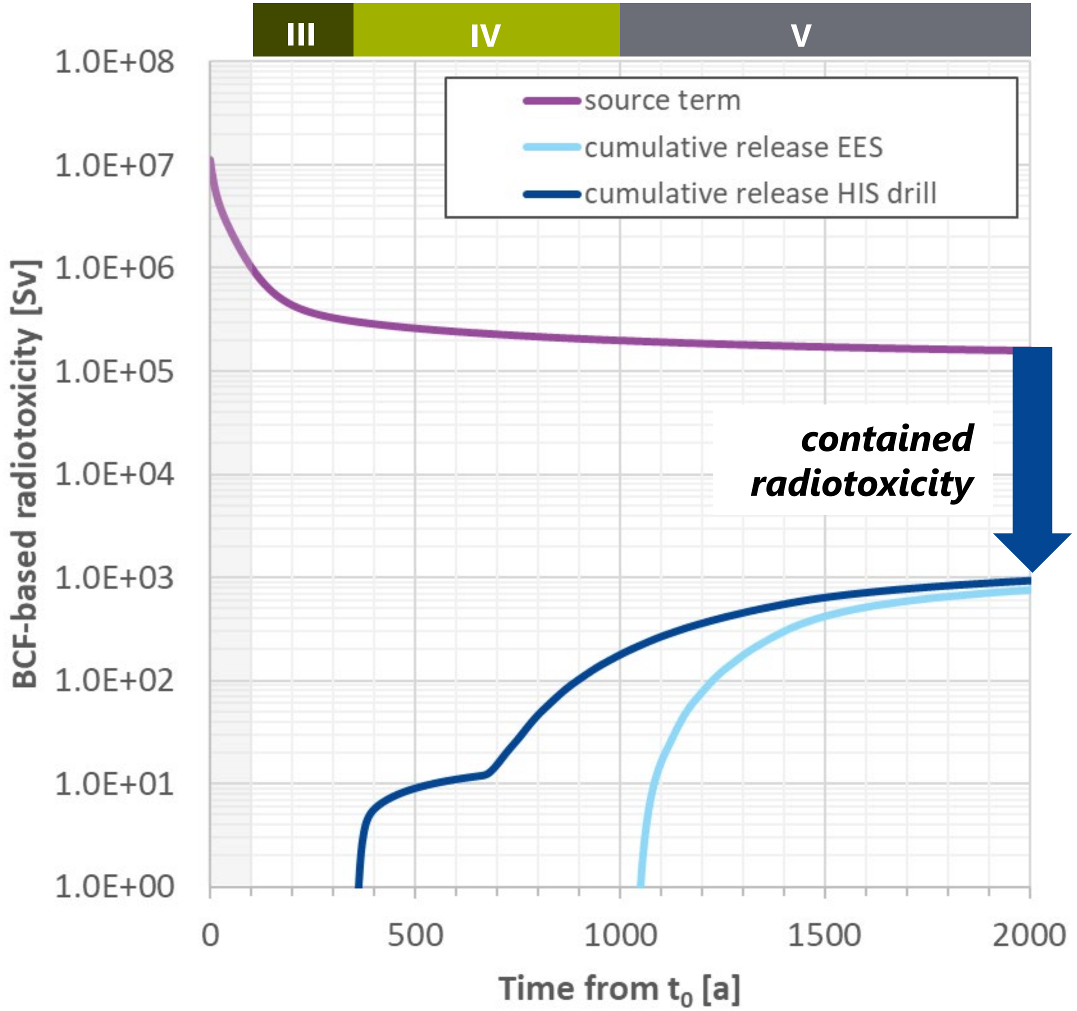


Theoretical transport time [a]

SORPTION

K_d [m^3/kg]	Inspection room 60 cm thick	Embankment 2 m thick
0	< 1 a	< 1 a
0,1	17 a	37 a
0,5	84 a	185 a
1	167 a	370 a
10	1 668 a	> 2 000 a

Bypass of conductive sorbing media (CSM)

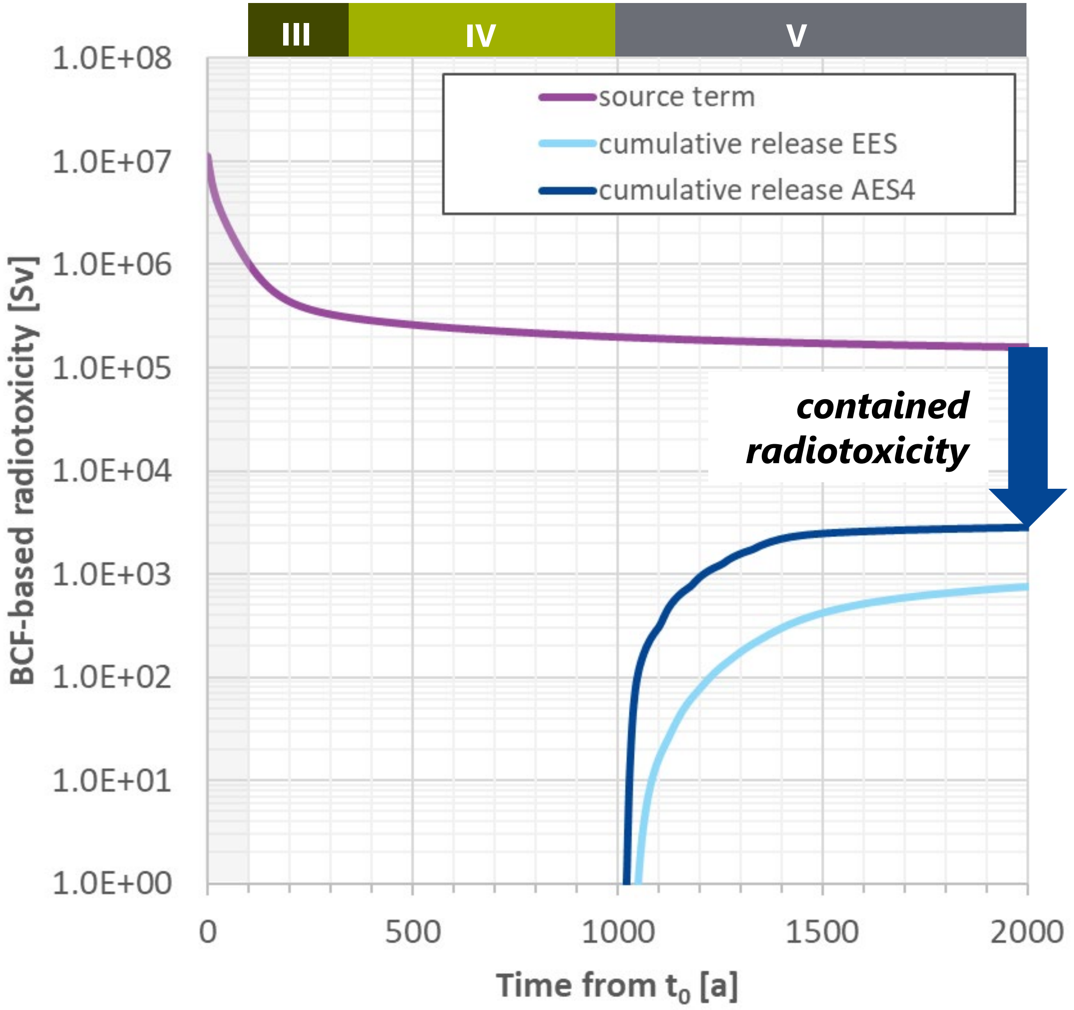


Cumulative released RT	EES	HIS drill
% of initial RT	0.0068	0.0084
% residual RT	0.48	0.59

Performance loss through bypass of CSM is compensated by:

- Efficient water diversion away from the waste (except for the pierced monolith stack) (R2a)
- Slow release from the waste form (R1/R3)

Internal disturbances (complexants)



Cumulative released RT	EES	AES4
% of initial RT	0.0068	0.0252
% residual RT	0.48	1.77

Local loss of sorption capacity due to undetected presence of complexants is compensated by:

- Protection by the cover (no *early* degradation)
- Efficient water diversion away from the waste (R2a)
- Slow release from the waste form and slow diffusion in the concrete/mortar matrix (R1/R4a)

Conclusions of FANC / Bel-V

R-SER-22-043-0-n

ONDRAF/NIRAS has performed a detailed performance analysis in which

- The complementarity of barriers and/or safety functions is demonstrated
- The disposal system shows an adequate level of robustness against reasonably foreseeable threats
- The performance of the disposal system is commensurate with the risks posed by the waste

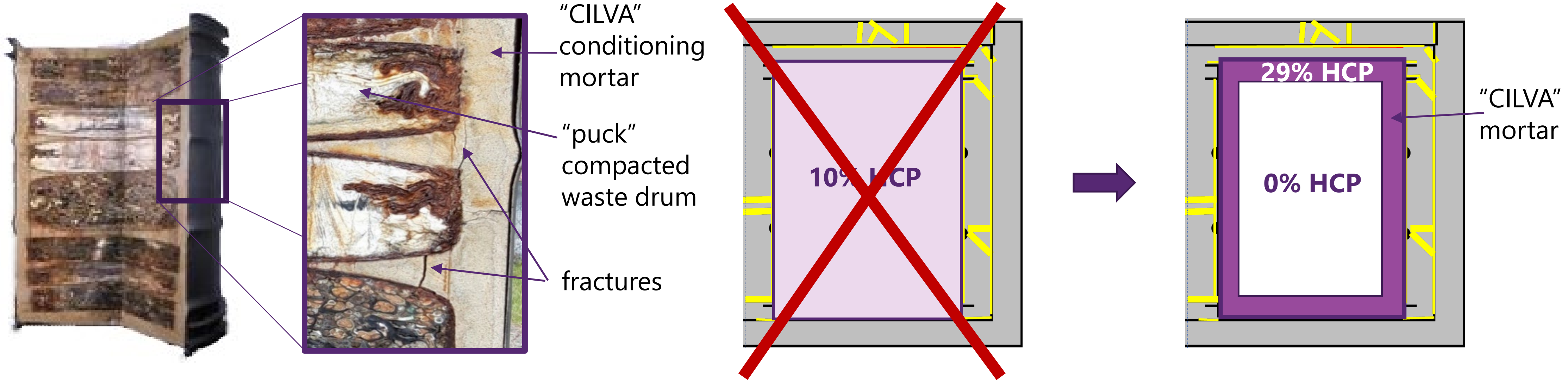
Conclusions of FANC / Bel-V

R-SER-22-043-0-n

The safety authority further asks to

- Update the impact analysis using the PA-model (one model for all)
- Evaluate the *bypass* potential for well-sorbed (class III) radionuclides in HEterogenously Cemented waste (HEC)

A potential "bypass" in HEC waste?



- To which degree can the sorption capacity in the conditioning mortar be bypassed by *well-sorbed* radionuclides that require some time to dissolve?
- Dedicated, representative model(s) in development…

The PA team

SCK CEN

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NIRAS

Elise Vermariën

References

SCK CEN report ER-0601 (OD-284)

§14.14 and §2.9

of the Safety Report

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Foundation of Public Utility

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