AF-Colenco Ltd

Bundesamt für Strahlenschutz

Safety and Performance Indicators for a Geological Repository in Clay

ZERNA INGENIEURE

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Objective

Quick and preliminary assessment of the efficiency of geological and geotechnical barriers

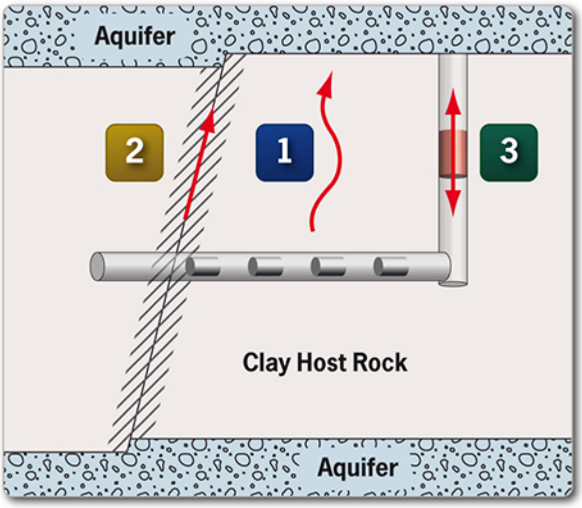
Approach

Solving the transport equations analytically with appropriately simplified boundary conditions

References

Charakterisierung von Barrierenwirksamkeiten im Mehrbarrierensystem für Endlager – Technische Barrieren und einschlusswirksamer Gebirgsbereich. Report to TA2 of the research project FKZ SR 2470A. Colenco Power Engineering Ltd, Zerna Ingenieure GmbH, Arius. Colenco-report 3470/06, Nov. 2007

Efficiency of Clay Barriers. Resele G., Niemeyer M., Heimer St., Colenco Power Engineering Ltd, Zerna Ingenieure GmbH. REPOSAFE Intern. Conference on Radioactive Waste Disposal in Geological Formations, Braunschweig (Germany) 6.-9.11.2007



Barrier indicators for:

General primary system parameters

- vertical transport distance H = 65 m
- vertical hydraulic gradient I = 0.5 m/m
- vertical hydraulic conductivity $K = 2{\cdot}10^{-14}$ m/s
- effective diffusivity
  - anions $D_e^{\perp} = 2{\cdot}10^{-12}$ m²/s, $D_e^{=} = 5{\cdot}10^{-12}$ m²/s
  - non-anions $D_e^{\perp} = 2{\cdot}10^{-11}$ m²/s, $D_e^{=} = 5{\cdot}10^{-11}$ m²/s
- porosity
  - anions n = 0.06
  - non-anions n = 0.12
- inverse advective Péclet number $\alpha_L = 0.1$

Examples of radionuclides

Se-79	$T_{1/2} = 1.1\cdot10^{6}$ a	R = 1
I-129	$T_{1/2} = 1.6\cdot10^{7}$ a	R = 2
Ca-41	$T_{1/2} = 1.0\cdot10^{5}$ a	R = 20
U-238	$T_{1/2} = 4.5\cdot10^{9}$ a	R = 400 000

Assessment time period t_{BZ} = 1 mio. years

1. Intact host rock

Derived characteristic system parameters:

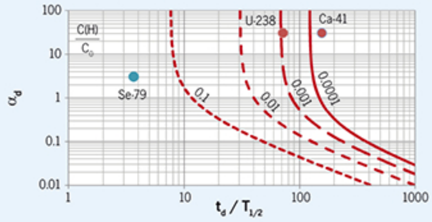
Characteristic time of diffusive transport $$t_d = \frac{H^2\cdot n\cdot R}{D_e^{\perp}}$$

Inverse diffusive Péclet number $$\alpha_d = \frac{D_e^{\perp}}{H\cdot K\cdot I}$$

$$\beta_{\pm}(t) = \frac{1}{2}\cdot\sqrt{\frac{\alpha_d}{\alpha_d+\alpha_L}}\cdot\sqrt{\frac{t_d}{t}}\cdot\left(1\pm\frac{t}{\alpha_d\cdot t_d}\right)$$

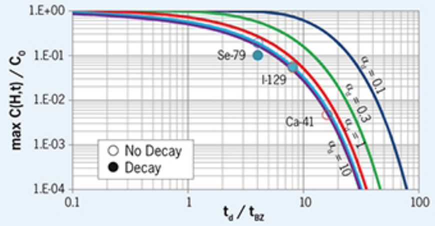
F1: Radionuclide retention versus radioactive decay under steady-state conditions

$$\frac{C(H)}{C_0} = \exp\left(\frac{1}{2}\cdot\frac{1}{\alpha_d+\alpha_L}\cdot\left\{1-\sqrt{1+4\,\lambda\,\alpha_d\,(\alpha_d+\alpha_L)\,t_d}\right\}\right)$$



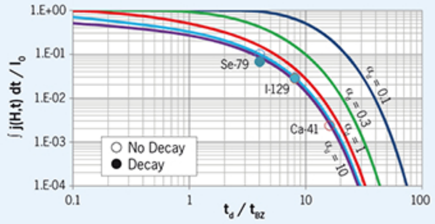
F2: Radionuclide retention for continuous release under transient conditions

$$\max_t\left(\frac{C(H,t)}{C_0}\right) = \max_t\left[e^{-\lambda t}\cdot\frac{1}{2}\cdot\left\{\mathrm{erfc}(\beta_-(t))+\exp\left(\frac{1}{\alpha_d+\alpha_L}\right)\cdot\mathrm{erfc}(\beta_+(t))\right\}\right]$$



F3: Radionuclide retention for a delta-peak release

$$\frac{1}{I_0}\cdot\int_0^{t_{BZ}} j(H,t)\,dt = \frac{1}{\sqrt{4\pi}}\cdot\int_0^{t_{BZ}} e^{-\lambda t}\cdot\frac{1}{t}\cdot\beta_+(t)\cdot\exp\left(-\beta_-^2(t)\right)dt$$



2. Fracture zone

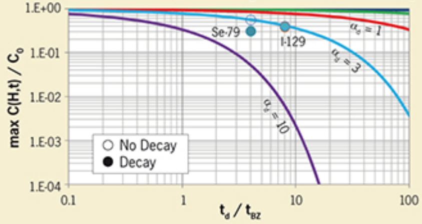
Additional system parameters:

Transmissivity of fracture zone $T_D = 3{\cdot}10^{-11}$ m²/s

Derived characteristic parameter $$\Omega = \frac{T_D}{H\cdot K}\cdot\sqrt{\frac{D_e^{\perp}}{D_e^{=}}}$$

F4: Radionuclide retention along the fracture zone for continuous release under transient conditions

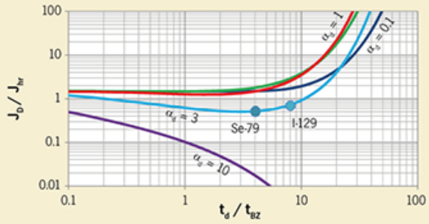
$$\max_t\left(\frac{C(H,t)}{C_0}\right) = \max_t\left[e^{-\lambda t}\cdot\mathrm{erfc}\left(\frac{\alpha_d}{\Omega}\cdot\sqrt{\frac{t_d}{t}}\right)\right]$$



or

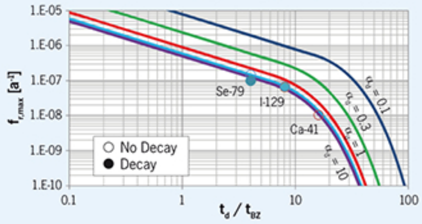
F4'': Ratio of radionuclide flux along the fracture zone to that through 1000 m of intact host rock

$$\frac{J_D}{J_{hr}} = \frac{H\cdot\sqrt{\frac{D_e^{=}}{D_e^{\perp}}}\cdot\Omega\cdot\max_t\left[e^{-\lambda t}\cdot\mathrm{erfc}\left(\frac{\alpha_d}{\Omega}\cdot\sqrt{\frac{t_d}{t}}\right)\right]}{1000\,\mathrm{m}\cdot\max_t\left[e^{-\lambda t}\cdot\left\{\frac{1}{2}\cdot\mathrm{erfc}(\beta_-(t))+\sqrt{\frac{\alpha_d\cdot(\alpha_d+\alpha_L)}{\pi}}\right\}\cdot\sqrt{\frac{t_d}{t}}\cdot\exp\left(-\beta_-^2(t)\right)\right]}$$



S1: Approximate dose from maximum radionuclide flux as a consequence of a delta-peak release

$$D = \frac{I_0\cdot DKF}{Q_{Bio}}\cdot f_{r,max}\qquad f_{r,max} = \frac{1}{\sqrt{4\pi}}\cdot\max_t\left[e^{-\lambda t}\cdot\frac{1}{t}\cdot\beta_+(t)\cdot\exp\left(-\beta_-^2(t)\right)\right]$$



3. Shaft seal

Additional system parameters:

Shaft seal hydraulic resistance $$P_{ss} = \frac{L_{ss}}{A_{ss}\cdot K_{ss}} = 3\cdot10^{10}\ \mathrm{s/m^2}$$

EDZ radius of infrastructural drifts $r_{EDZ} = 4$ m

Transport distance along drifts and shaft Y = 1000 m

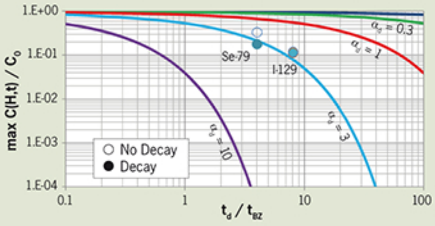
F7: Ratio of water flow to the repository along the shaft to water flow from intact host rock after sealing the repository

$$\frac{Q_{ss}}{Q_{hr}} = \frac{\ln(2H/r_{EDZ})-0.45}{P_{ss}\cdot2\,\pi\cdot K\cdot5000\,\mathrm{m}}$$

P_{ss} [s/m²]	$1\cdot10^{10}$	$3\cdot10^{10}$	$1\cdot10^{11}$
Q_{ss} / Q_{hr}	0.48	0.16	0.05

F8: Radionuclide retention along drifts and shaft for continuous release under transient conditions

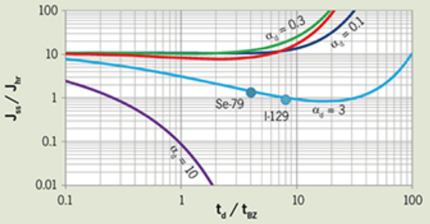
$$\max_t\left(\frac{C(H,t)}{C_0}\right) = \max_t\left[e^{-\lambda t}\cdot\mathrm{erfc}\left(P_{ss}\cdot Y\cdot\frac{\pi\cdot r_{EDZ}\cdot K}{H}\cdot\sqrt[4]{\frac{D_e^{=}}{D_e^{\perp}}}\cdot\alpha_d\cdot\sqrt{\frac{t_d}{t}}\right)\right]$$



or

F11: Ratio of radionuclide flux along drifts / shaft to that through 10 000 m² of intact host rock

$$\frac{J_{ss}}{J_{hr}} = \frac{\frac{H}{P_{ss}}\cdot\max_t\left[e^{-\lambda t}\cdot\mathrm{erfc}\left(P_{ss}\cdot Y\cdot\frac{\pi\cdot r_{EDZ}\cdot K}{H}\cdot\sqrt[4]{\frac{D_e^{=}}{D_e^{\perp}}}\cdot\alpha_d\cdot\sqrt{\frac{t_d}{t}}\right)\right]}{10^4\mathrm{m}^2\cdot K\cdot\max_t\left[e^{-\lambda t}\cdot\left\{\frac{1}{2}\cdot\mathrm{erfc}(\beta_-(t))+\sqrt{\frac{\alpha_d\cdot(\alpha_d+\alpha_L)}{\pi}}\right\}\cdot\sqrt{\frac{t_d}{t}}\cdot\exp\left(-\beta_-^2(t)\right)\right]}$$



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Nantes 2010: Clays in Natural & Engineered Barriers for Radioactive Waste Confinement,
4th International Meeting, March 29th-April 1st, 2010