

3th September 2019 Henrik Nordman (I have experience from different safety analyses for waste repository last 30 years. Not a radon expert so some open questions.

Cores Symposium

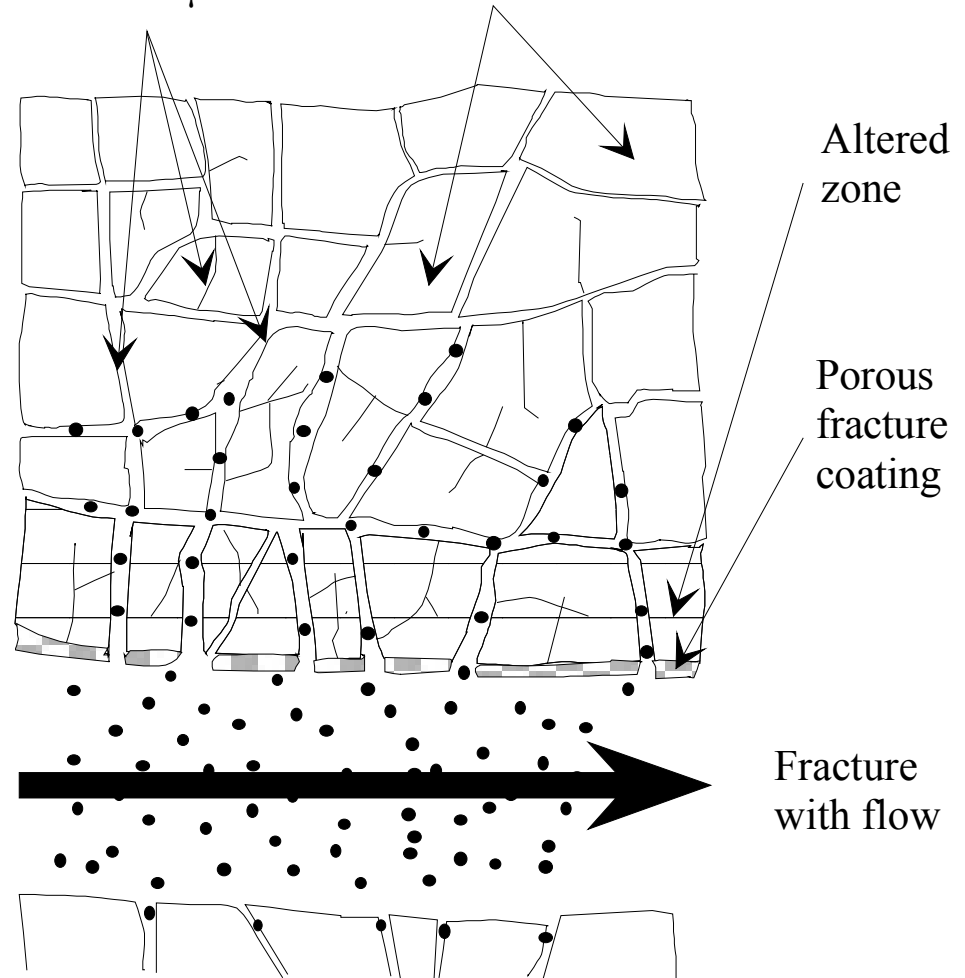
Radon transport from radium in disposed waste

Diffusion of nuclides migrating from repository to surface.
Old folklore was that radium will be jammed in rock matrix
Retardation parameter is K_d (m^3/kg) to rock minerals

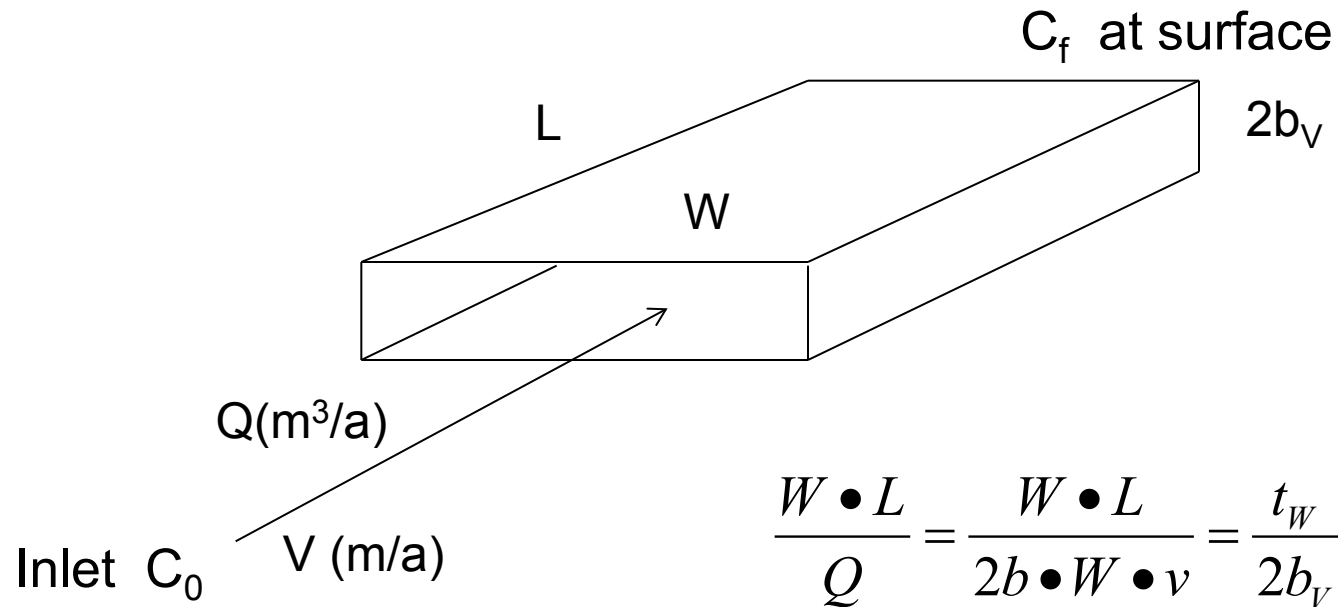
Microfractures
with diffusion
0.01 - 10 μm

Mineral grains
0.1 - 10 mm

- Rock matrix is porous
- Sucking nuclides from fracture



WL/Q Geometry of flow channel from repository to surface and u parameter which dominates release rate



- W =width, L = length, Q = flow rate, $2b$ = fracture aperture, t_w travel time
 - Constant inlet C_0 then at surface **$C_f(L, t) = C_0 \operatorname{erfc} [u t^{-1/2}]$**
 - $u = [D_e \varepsilon_p R_p]^{1/2} \times WL/Q = [D_e (\varepsilon_p + K_d \rho_s)]^{1/2} \times WL/Q$
 - Rock properties: D_e =effective diffusion coefficient ε_p = porosity
- K_d = distribution coefficient ρ_s =density

Delta pulse input. At surface maximum release

$$\text{time } t_{\max} = t_w + 2u^2/3 \text{ and } m_{\max} = 0.23/u^2$$

$$u_{\text{sorbing}} \approx [D_e K_d \rho_s]^{1/2} \cdot \frac{W L}{Q}$$

- In old times K_d was as high as 0.2 (m³/kg) **but today orders of magnitude lower**
- And $T_{1/2}$ of radium is 1600 years. In Below table you see the effect for on input rate of 4E+5 Bq/yr. Scoping results from EU PAMINA project year 2009

Case	Allowed depth (m)	WL/Q (a/m)	K_d (m ³ /kg)	D_e (m ² /s)	u (a ^{1/2})	t_{\max} for delta Pulse (a)	max. from geosphere (Bq/a)
Ra1	0.1	5 000	0.02	10 ⁻¹⁴	20.6	2.8E+2	1.70E+5 *
Ra2	0.1	5 000	0.2	10 ⁻¹⁴	65	2.8E+3	2.59E+4
Ra3	0.1	50 000	0.02	10 ⁻¹⁴	206	2.8E+4	8.32E+1 **

- $t_{\max} = t_w + 2u^2/3$ so when u is only 20 yr ($u^2 = 400$ yr) radium is released fast ($T_{1/2}=1600$ yr)

Now Rn-222 from Ra-226 in geosphere. Natural analogue.

- In natural well water Rn-222 concentration is orders of magnitude higher than Ra-226 (Bq/m³)
- BIG question. How much analogue to a release from waste repository and Rn-222/Ra-226 relation in well water.
- In drilled well: Natural Rn-222 concentration is 10,000 higher (mean 460 Bq/L) than Ra-226 (mean 0.05 Bq/L). Uranium content mean 0.26 to 0.35 Bq/L
- Normal well and ground water: Rn-222 concentration 3333 times higher than Ra-226
- Reference above is STUK1 and Table 1, not very analogue to waste.
- Natural waters seem to have a minimum 200 times Rn-222 concentration compared to radium. Originating from uranium in rock minerals or.

Reference: STUK1= <http://www.stuk.fi/aiheet/elintarvikkeet-ja-juomavesi/juomavesi>

Horror calculation using natural Rn-222/Ra-226 relation (how analogue to Ra-226 coming from repository ???).

- So near field Ra-226 release rate $4E+5$ Bq/yr is decreased to e.g. $1E+4$ Bq/yr at geosphere migration. Not very pessimistic in fact with today's low K_d values.
- If this $1E+4$ Bq/yr is diluted to 1000 m³/yr then the Ra-226 concentration in drilled well is 10 Bq/m³.
- $Rn-222/Ra-226 = 10,000$? $\Rightarrow 100,000$ Bq/m³ of Rn-222 ($10000 * 10$ Bq/m³) in drilled well water (NOT this way of course).
- Causing in house air a concentration of 10 Bq/m³ (STUK2).
- Causing a dose of 0.17 mSv/yr (STUK2).
- BUT Rn-222 concentration is not 10000 times Ra-226 concentration. Uranium near well in rock material is dominant to well concentration or ????

Reference:

STUK2 = https://www.stuk.fi/documents/12547/494524/kirja2_4.pdf/e4ad6bfe-b60f-4394-b6a5-049d9c63e148

Finally Rn-222 from Ra-226 in geosphere with a computer model. A bit problematic to model.

- GOLDSIM code tests
 - With GoldSim tests didn't get big difference (less than 10 % Rn-222 versus Ra-226) in concentration (10 m³ of water a biosphere cell in GOLDSIM).
 - Release rates of Rn-222 to well could be orders of magnitude higher with GoldSim. But not the concentration in well.
- So should there be uranium in the vicinity of drilled well in order to get high Rn-222 concentrations. Ra-226 alone in water is not enough ??
- Please answer or links regarding origin of Rn-222/Ra-226 relation in natural waters. Henrik.Nordman@vtt.fi