Radon in an underground NORM repository

Per Varskog, Norse Decom AS, Norway
Hartmut Schulz, IAF Radioökologie GmbH, Germany

NORSE DECOM

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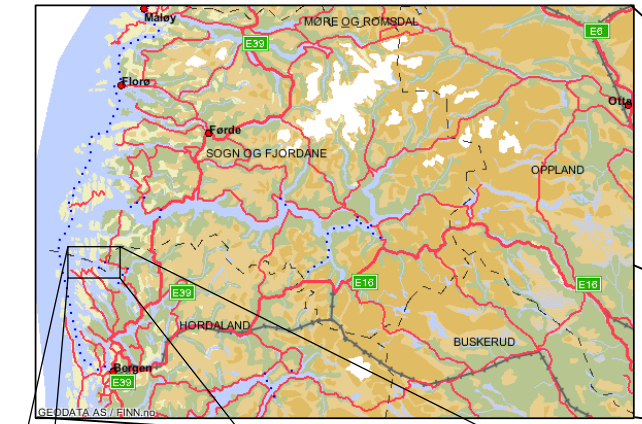
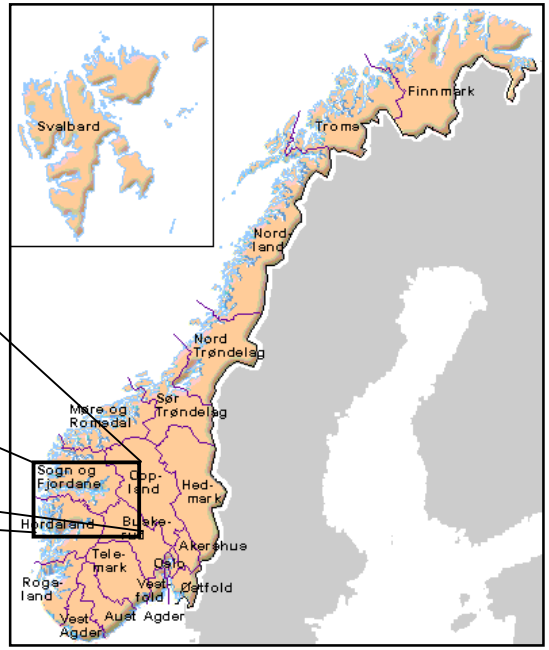
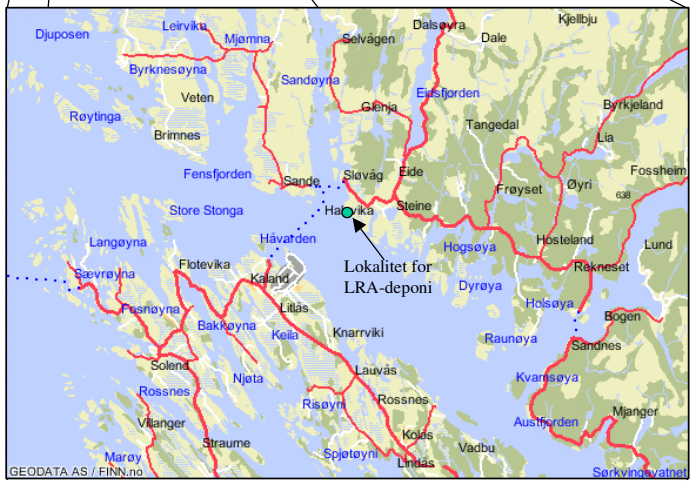
IAF
RADIOÖKOLOGIE GmbH
Labor für Radionuklidanalytik • Radioökologische Gutachten • Consulting

Location







The disposal site is located at Sløvåg in Sogn og Fjordane County, Norway.

The facility was opened in October 2008.

Capacity to receive all European oil and gas industry generated NORM.

Stangeneset NORM Disposal Site

Dimensions						
Tunnel No.	Gradient	Width	Height	Length	Volume	Capacity
		m	m	m	m^3	tons
1	1 : 100	8	5	45	1800	
2	1 : 100	12	6	60	4320	
3	- 1: 7	4	4	130	2080	
4	1 : 100	10	5	60	3000	4500
5	1 : 100	10	5	34	1700	2550
6	1 : 100	5	4	60	1200	

Typical Activity Ranges in Sludge and Scale

Oil company	Mass (tons)	Composition (weight %)				
		Water	Heavy oil components	Sulphates	Corrosion products	Sand/clay
Company A	166	23.6	7.4	45.7	8.5	14.8
Company B	4.1	15.9	1.4	77.9	2.0	2.8
Company C	0.5	11.8	1.5	75.4	6.8	4.5
Company D	17.0	45.4	6.6	39.0	6.1	2.9

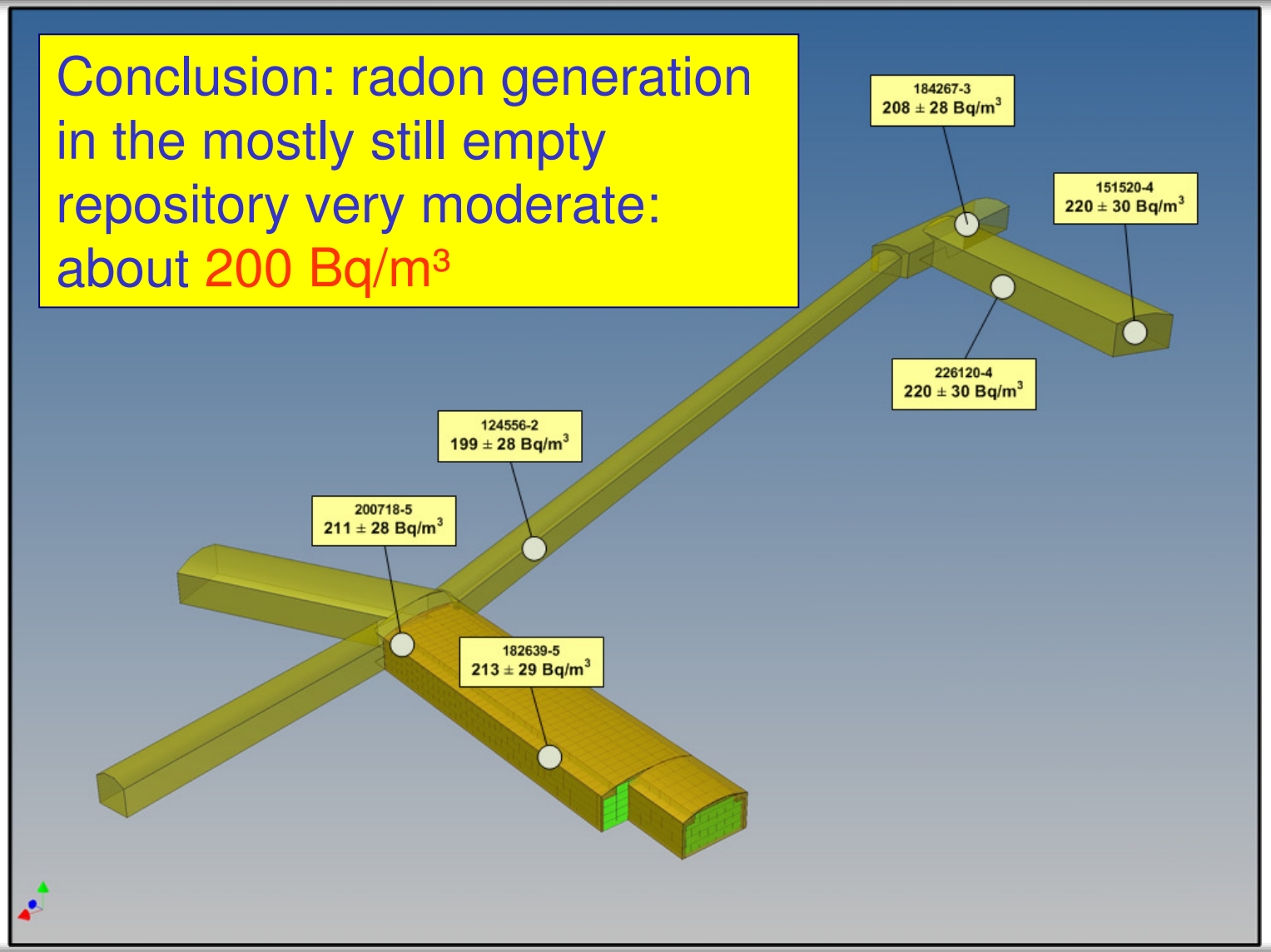
Oil company	Activity concentration (Bq/g)		
	^{226}Ra	^{228}Ra	^{210}Pb
Company A	21.5 (9.7 – 74.1)	11.2 (3.3 – 28.9)	2.4 (<0.2 – 11.8)
Company B	19.3 (16.3-23.6)	7.3 (6.4-8.6)	2.7 (2.0-3.7)
Company C	20.8	9.6	1.8
Company D	40.4 (4.9-100)	3.7 (0.4-13-3)	13.8 (2.3-49)

Typical Drums in Repository

Radon by passive dosimeters

Measurement period 10.11.11 – 01.02.11

Conclusion: radon generation in the mostly still empty repository very moderate: about 200 Bq/m³



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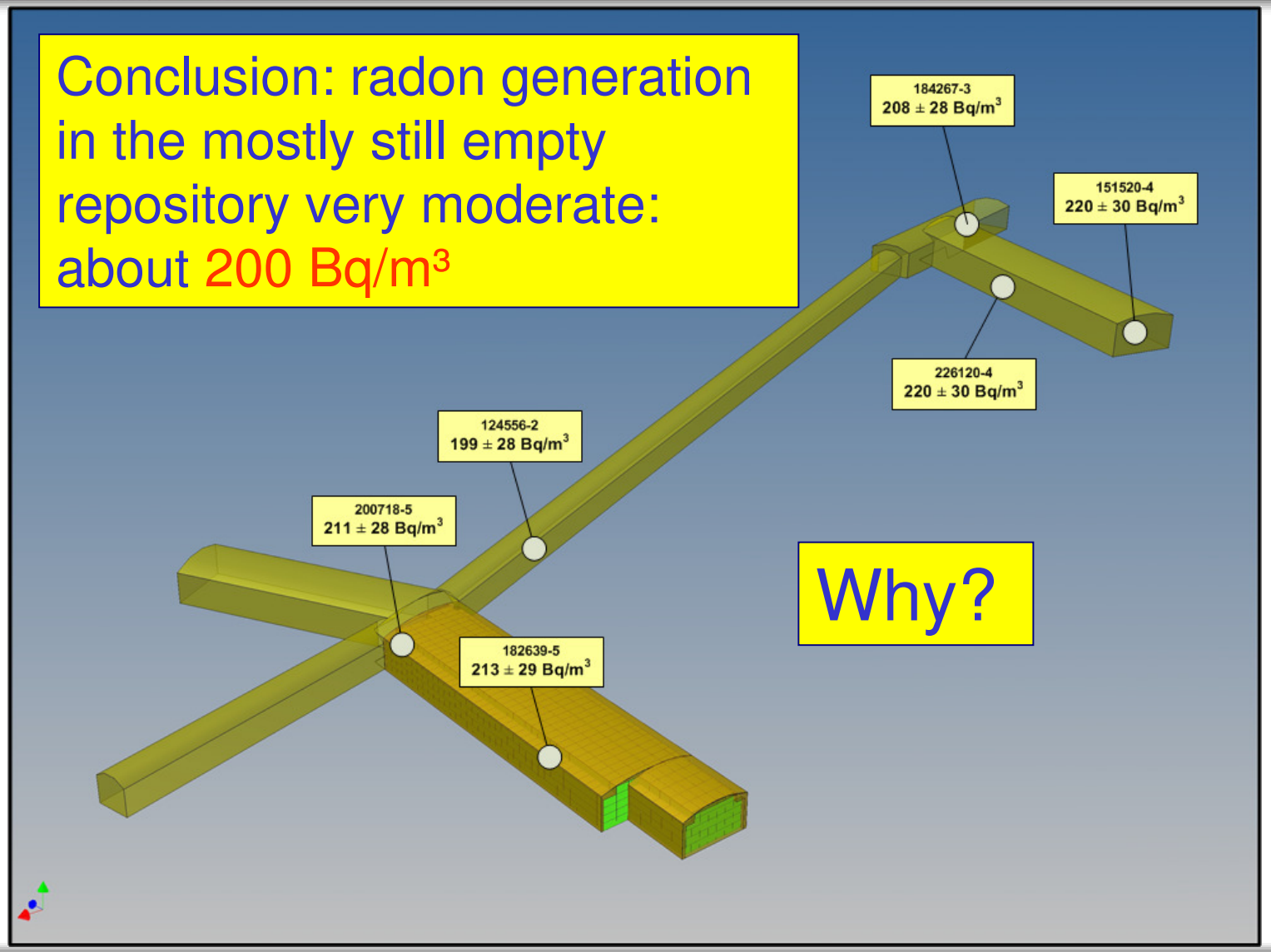
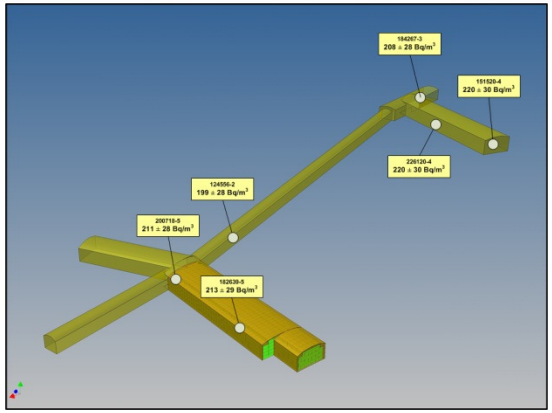


Why is the Radon Concentration so Moderate?



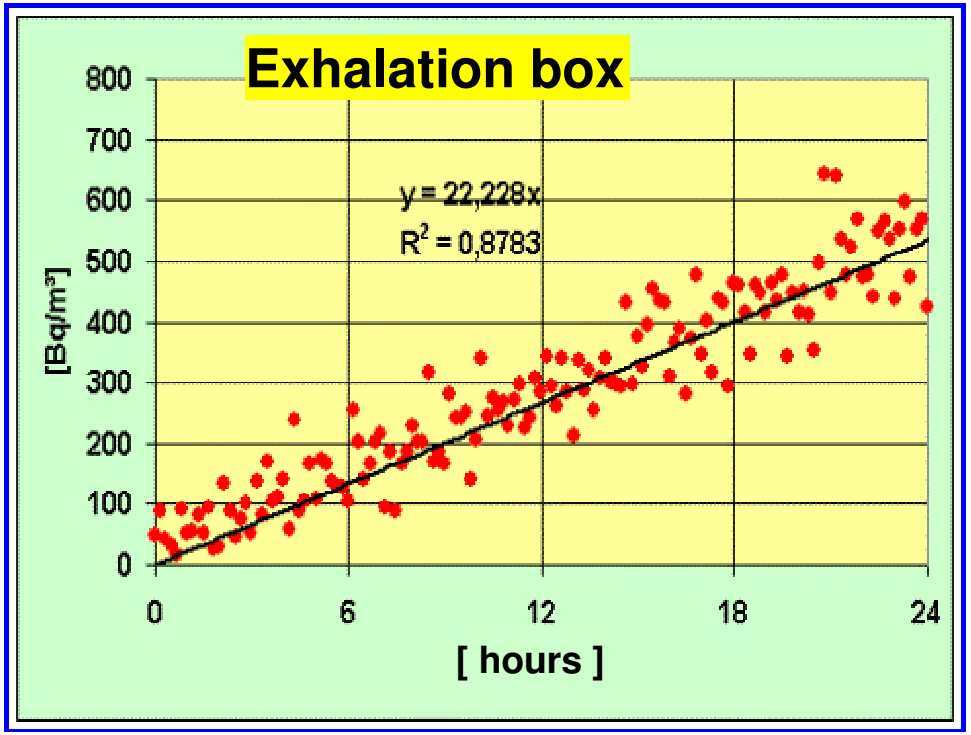
Walls: gneissic rock

Ground Floor: concrete

Barrels: mostly closed

Why is the radon concentration fairly moderate inside the repository?

Radon Generation of Dry Scales



in a closed tubing 25.000 Bq/m³ of radon could be reached

[thickness] [mm]	Ra-226 [Bq/g]	[exhalation rate] [Bq/(m² s)]	[exhalation rate] [Bq/(m² h)]	[diffusion parameter] [m²/s]
2,7	440	0,0068	25	$5{,}5 \cdot 10^{-18}$

Radon Generation of Sludge

Practically radon exhalation of sludge of minor importance

Why?

	K_d
Diesel / Water	39,8 ± 4
Benzine / Water	52,3 ± 6
Air / Water	≈ 4

$$K_d = \frac{c_{Oil}\left[\frac{Bq}{l}\right]}{c_w\left[\frac{Bq}{l}\right]}$$

Exhalation Rates of Gneissic Rocks and Concrete

Material	Ra-226 Bq/kg		Th-232 Bq/kg		K-40 Bq/kg	
	mean value	interval	mean value	interval	mean value	interval
Granite	100	(30 - 500)	120	(17 - 311)	1000	(600 - 4000)
Gneissic rock	75	(50 - 157)	43	(22 - 50)	900	(830 - 1500)

Activity ranges

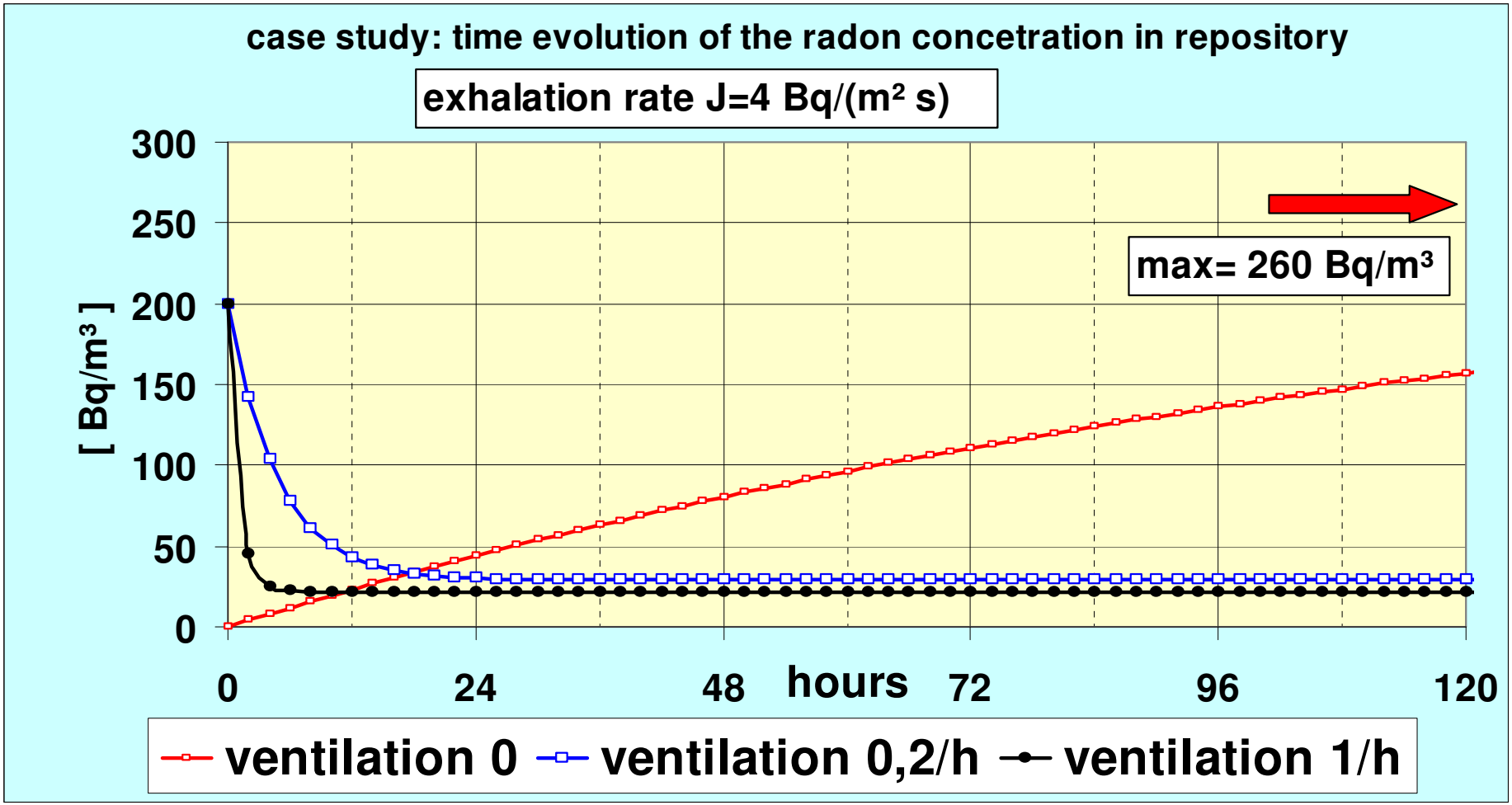
Material	Emanation E
	mean value
Granite	0,33
Gneissic rock	0,14

emanation

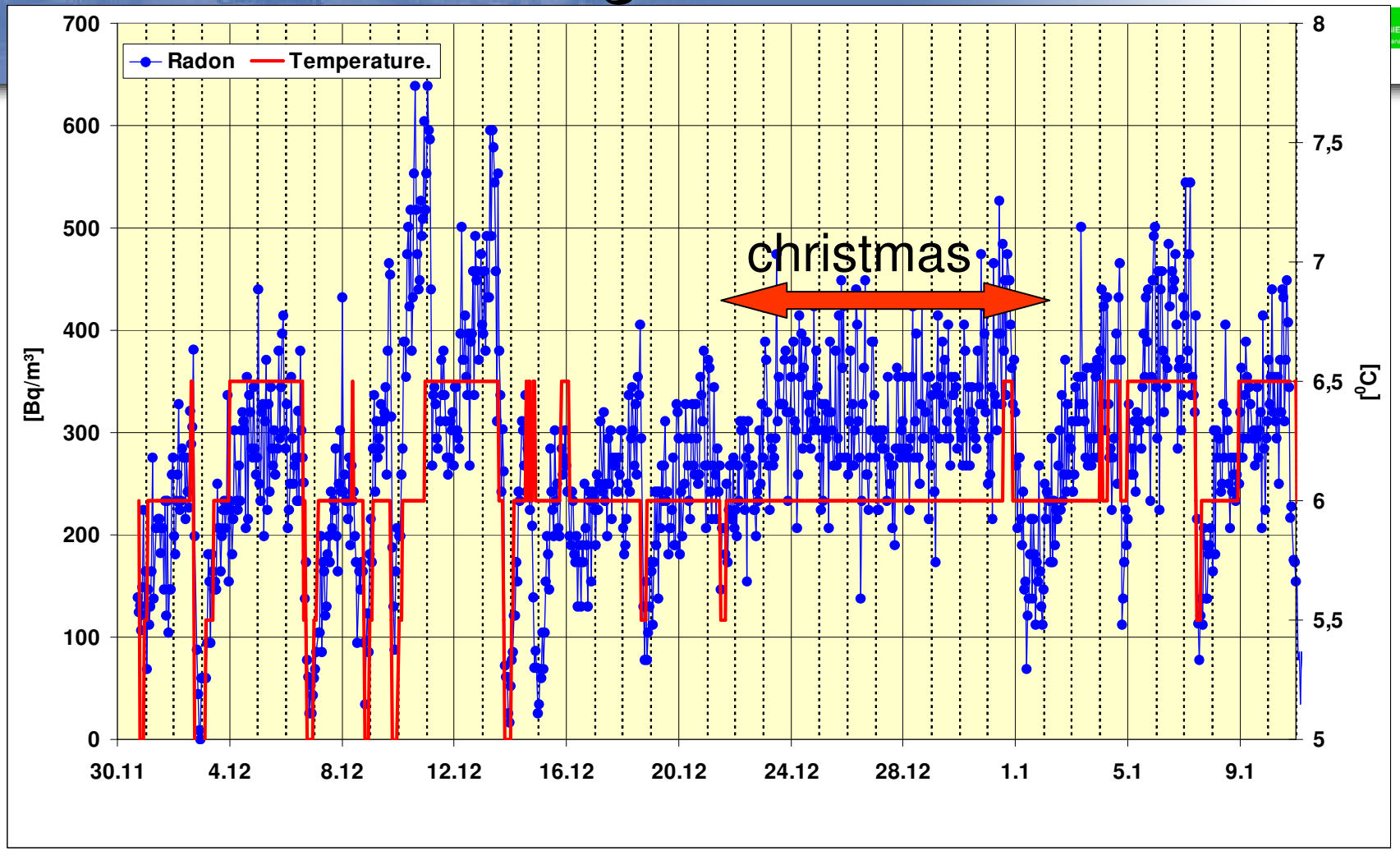
Material	Exhalation rate
	[Bq/(m² h)]
concrete	1 - 20
Gneissic rock	1 - 3

exhalation rate

Case study: time evolution of the radon concentration in the repository



Radon Monitoring



- No ventilation: constant Radon concentration
- Temperature changes according to ventilation
- Drop in temperature associated with radon reduction and vice verse

Work in Conditioning Tunnel

Pallet Unpacking (closed drums)

Work in Conditioning Tunnel

Weighing (closed drums)

Work in Conditioning Tunnel

Drum Opening and Closing (open drums)

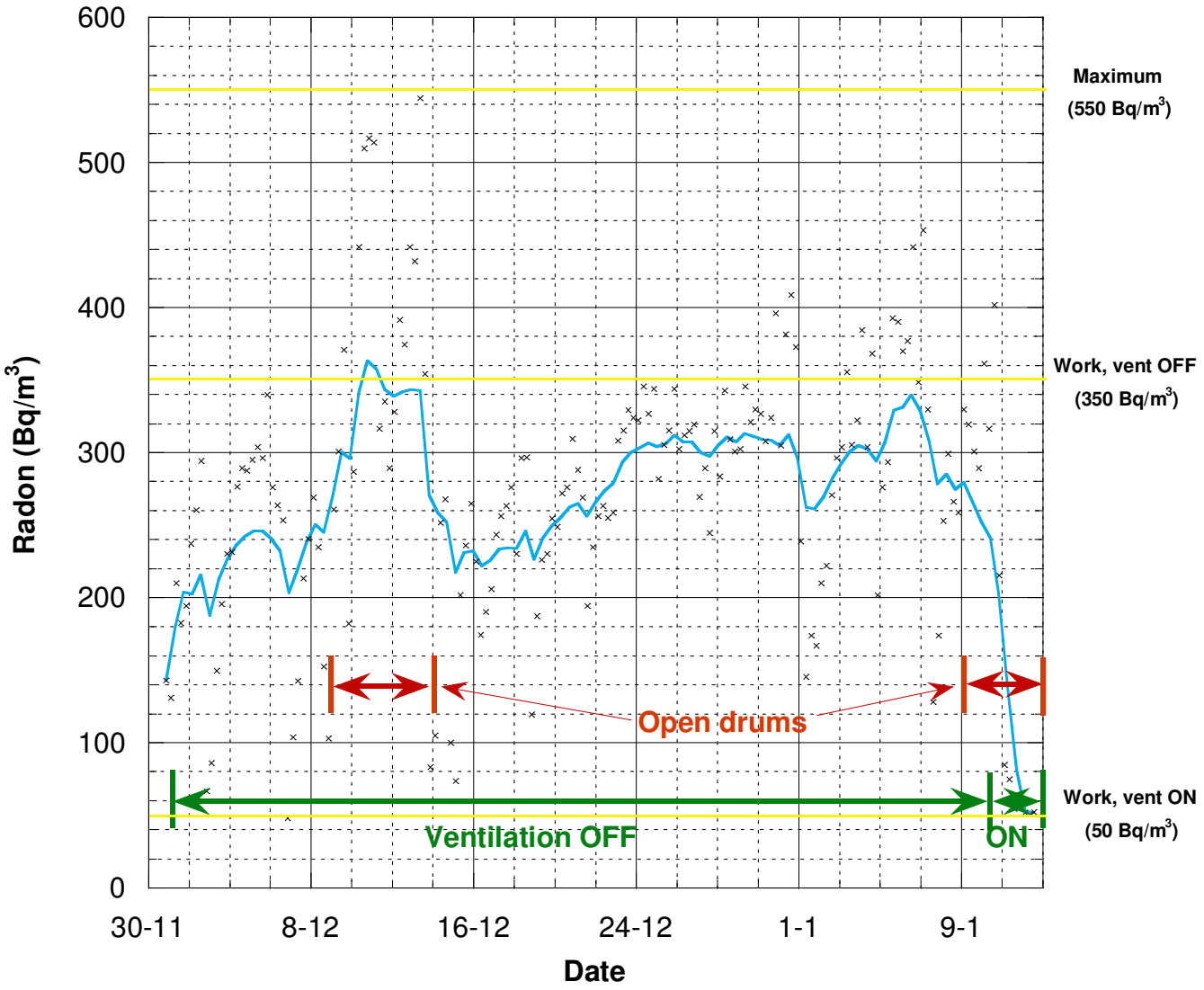
Work in Conditioning Tunnel

Drum Topping (open drums)

Work in Conditioning Tunnel

Transport to Repository (closed drums)

Radon in Conditioning Tunnel (30.11.10 – 13.01.11)



Radon doses, equilibrium factor f=0,4

2010		Radon dose (µSv)		
	Hours	Maximum (550 Bq/m³)	Work, vent OFF (350 Bq/m³)	Work, vent ON (50 Bq/m³)
Worker 1	80,5	**0,138**	**0,088**	**0,013**
Worker 2	66,5	**0,114**	**0,073**	**0,010**
Worker 3	60,0	**0,103**	**0,066**	**0,009**
2011		Radon dose (µSv)		
	Hours	Maximum (550 Bq/m³)	Work, vent OFF (350 Bq/m³)	Work, vent ON (50 Bq/m³)
Worker 1	118,0	**0,202**	**0,129**	**0,018**
Worker 2	64,5	**0,111**	**0,070**	**0,010**
Worker 3	52,5	**0,090**	**0,057**	**0,008**

Conclusions

- During the 40 days monitoring period the radon concentration in the repository was found to vary between 550 Bq/m3 and 50 Bq/m^3 with the lower value as the typical working condition.
- The resulting doses received by workers are low: less than 0.1 µSv/year.
- Ventilation effectively reduces the radon concentration (Outdoor radon typically 10 Bq/m3)
- Case study shows that the tunnel walls are the main contributor to the radon in the repository.