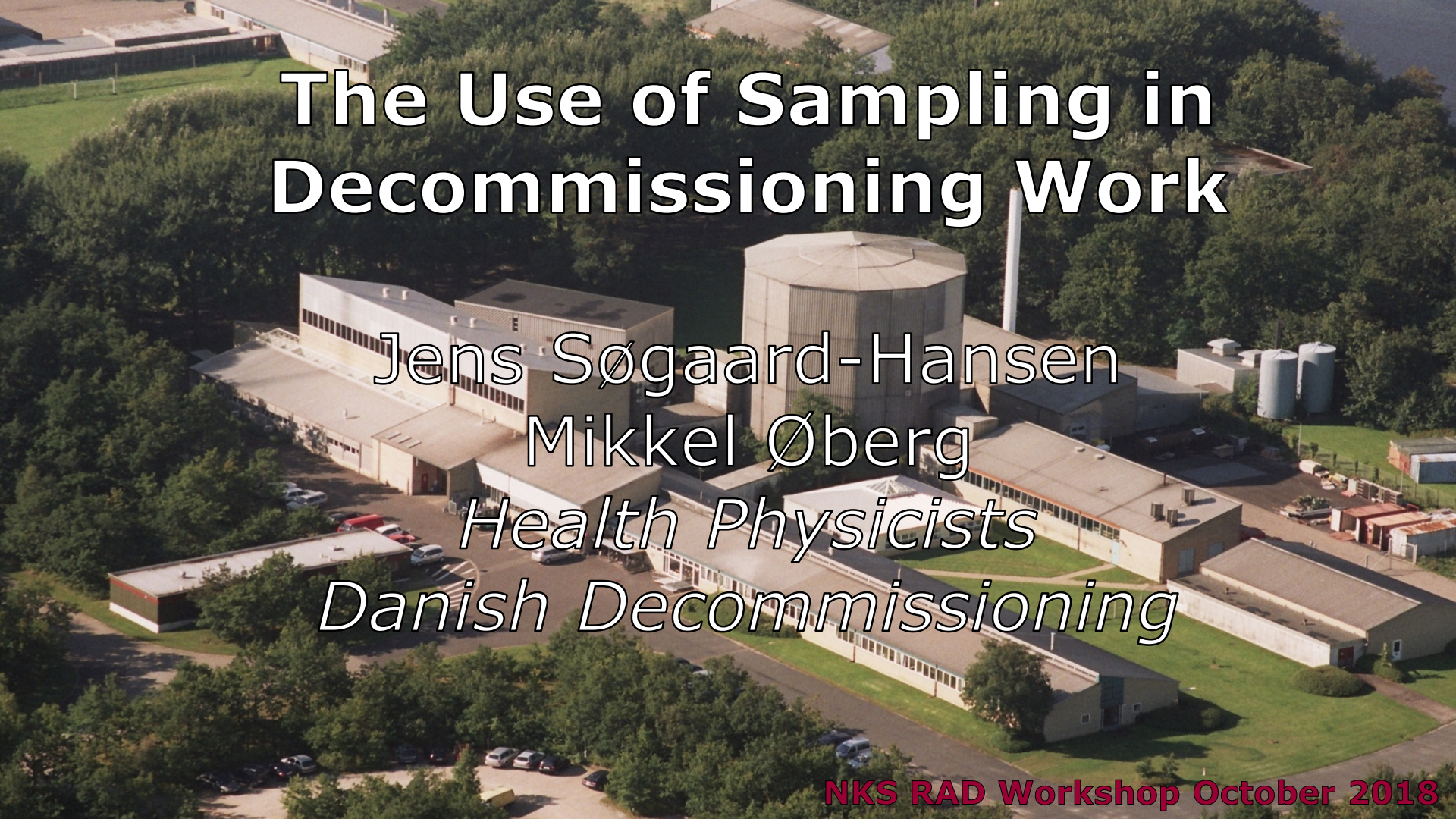


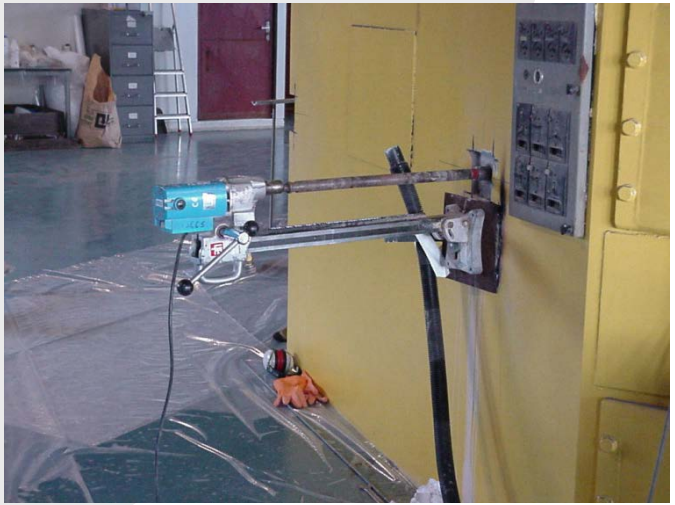
The Use of Sampling in Decommissioning Work

Jens Søgaard-Hansen
Mikkel Øberg
Health Physicists
Danish Decommissioning

NKS RAD Workshop October 2018

Characterization prior to decommissioning

➢ Structures



DANSK DEKOMMISSIONERING

Characterization prior to decommissioning

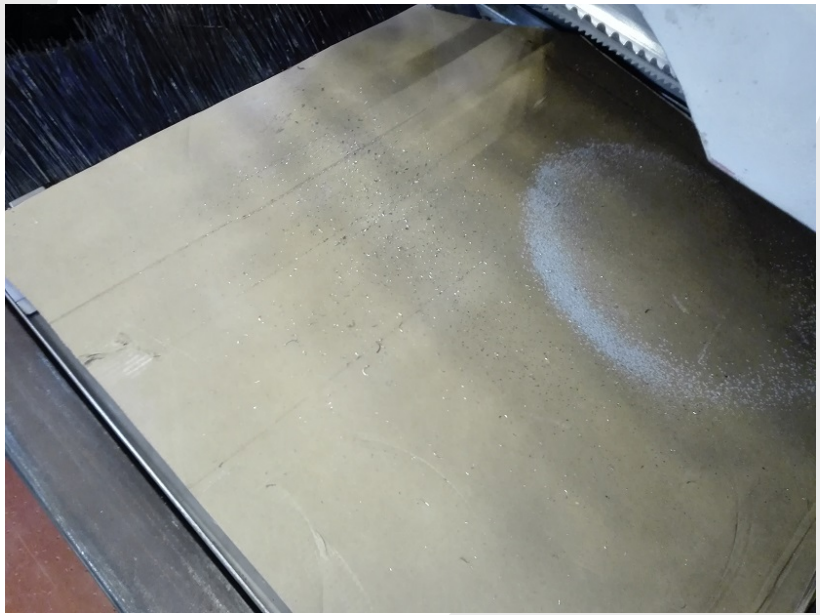
➢ Stored items

Dose rate [mSv/h]
285
540
565
525
430
260
120
37
15
12
10
4
0.425
0.135
0.050

DANSK DEKOMMISSIONERING

Characterization during decommissioning

➢ Waste items



DANSK DEKOMMISSIONERING

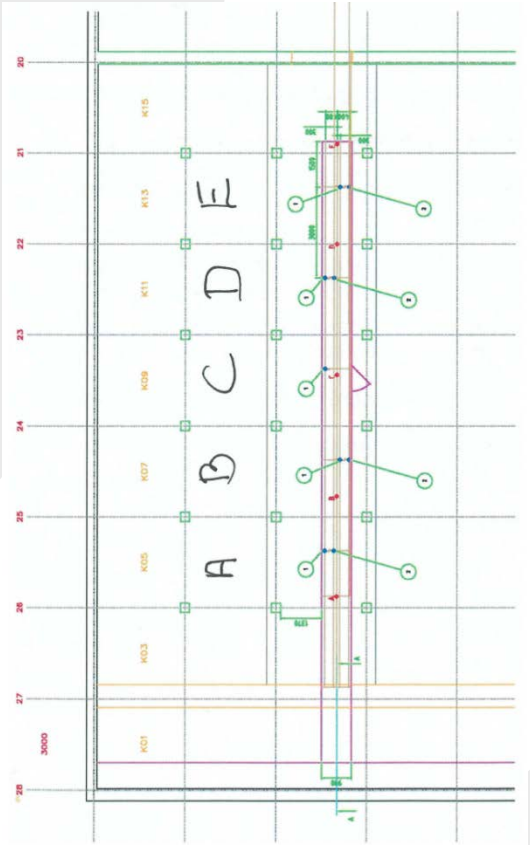
Characterization during decommissioning

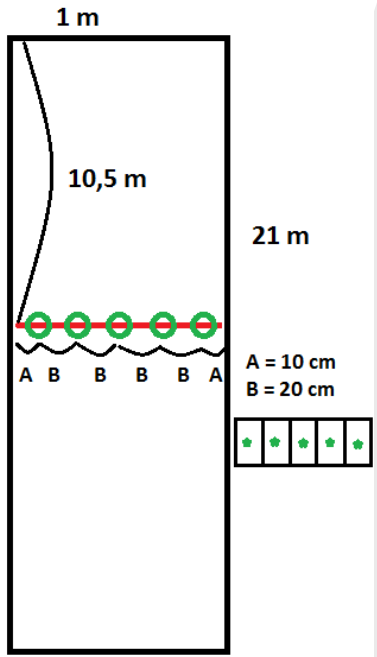
➢ Installations

DANSK DEKOMMISSIONERING

Characterization during decommissioning

➢ Buildings





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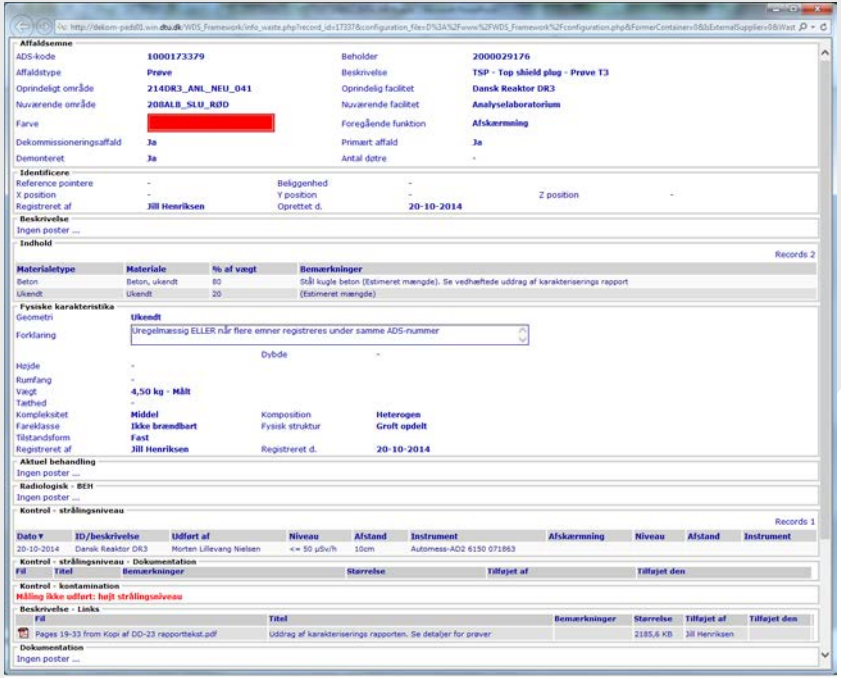
Characterization during decommissioning

➢ Release of Cl-36?

- Paper sample
- Water sample
- Grass samples

DANSK DEKOMMISSIONERING

Characterization after decommissioning



Affaldsemne

ADS-kode	1000173379	Beholder	2000029176
Affaldstype	Prøve	Beskrivelse	TSP - Top shield plug - Prøve T3
Oprindeligt område	214DR3_ANL_NEU_041	Oprindelig facilitet	Dansk Reaktor DR3
Nuværende område	208ALB_SLU_RØD	Nuværende facilitet	Analyselaboratorium
Farve		Foregående funktion	Afskærmning
Dekommissioneringsaffald	Ja	Primært affald	Ja
Demonteret	Ja	Antal døre	-

Identificere

Reference pointere	-	Beliggenhed	-		
X position	-	Y position	-	Z position	-
Registreret af	Jill Henriksen	Oprettet d.	20-10-2014		

Beskrivelse

Ingen poster ...

Indhold

Records 2

Materialetype	Materiale	% af vægt	Bemærkninger
Beton	Beton, ukendt	80	Stål kugle beton (Estimeret mængde). Se vedhæftede uddrag af karakteriserings rapport
Ukendt	Ukendt	20	(Estimeret mængde)

Fysiske karakteristika

Geometri	Ukendt				
Forklaring	Uregelmæssig ELLER når flere emner registreres under samme ADS-nummer				
		Dybde	-		
Højde	-				
Rumfang	-				
Vægt	4,50 kg - Målt				
Tæthed	-				
Kompleksitet	Middel	Komposition	Heterogen		
Fareklasse	Ikke brændbart	Fysisk struktur	Groft opdelt		
Tilstandsform	Fast				
Registreret af	Jill Henriksen	Registreret d.	20-10-2014		

Aktuel behandling

Ingen poster ...

Radiologisk - BEH

Ingen poster ...

Kontrol - strålingsniveau

Records 1

Dato	ID/beskrivelse	Udført af	Niveau	Afstand	Instrument	Afskærmning	Niveau	Afstand	Instrument
20-10-2014	Dansk Reaktor DR3	Morten Lillevang Nielsen	<= 50 µSv/h	10cm	Automess-AD2 6150 071863				

Kontrol - strålingsniveau - Dokumentation

Fil	Titel	Bemærkninger	Størrelse	Tilføjet af	Tilføjet den

Kontrol - kontamination

Måling ikke udført: højt strålingsniveau

Beskrivelse - Links

Fil	Titel	Bemærkninger	Størrelse	Tilføjet af	Tilføjet den
Pages 19-33 from Kopi af DD-23 rapporttekst.pdf	Uddrag af karakteriserings rapporten. Se detaljer for prøver		2185,6 KB	Jill Henriksen	

Dokumentation

Ingen poster ...

DANSK DEKOMMISSIONERING

Indirect measurements

Sample Measurement Parameters:
Comment: EBS sågmotor
User: Peter Enqvist
Preset Time: 2:00
Alpha Preset Error: 1,0%
User Protocol: Strykprov 2 min

Instrument Name: LB 770-2 sn 42361-6236
Cycles: 1
Beta Preset Error: 1,0%

Cycle 1 of 1
Start Time: 2015-10-29 11:42:31

Elapsed Time: 2:00
Guard: 13,75 cps

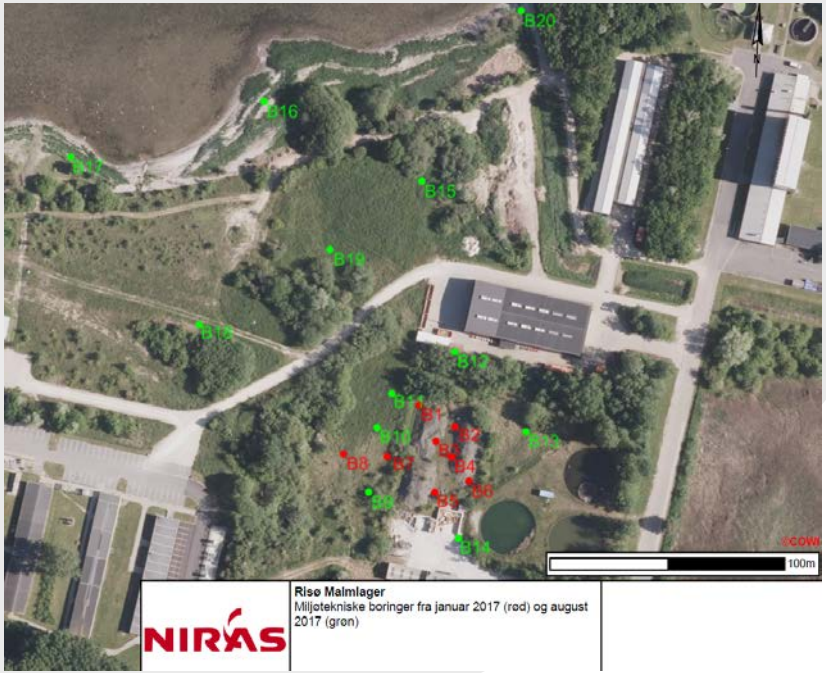
	Spl #	Sample Name	Alpha (kBq/m2)	Cat	MDA	MRA	Beta (kBq/m2)	Cat	MDA	MRA
1	11	Motor	0,031 (±74,3%)	1	0,0605	0,0083	11,94 (±4,17%)	2	0,2189	0,0844
2	12	Motor	0,030 (±78,4%)	1	0,0697	0,0122	19,35 (±3,42%)	2	0,2910	0,1200
3	13	Motor	0,030 (±75,7%)	1	0,0638	0,0098	20,45 (±3,32%)	2	0,2294	0,0899
4	14	Motor	0,065 (±51,2%)	1	0,0626	0,0086	8,445 (±4,85%)	2	0,2413	0,0937
5	15	Kabel	0,049 (±59,5%)	1	0,0632	0,0085	0,961 (±15,3%)	1	0,2545	0,1009
6	16	6Kabel	0,000	1	0,0665	0,0100	0,614 (±19,4%)	1	0,2353	0,0936
7	17	7Kabel	0,015 (>100%)	1	0,0664	0,0097	0,895 (±15,8%)	1	0,2440	0,0968
8	18	8Kabel	0,000	1	0,0659	0,0092	0,371 (±26,2%)	1	0,2240	0,0879
9	19	9Kabel	0,000	1	0,0640	0,0086	0,173 (±45,2%)	1	0,2287	0,0893
10	20	Kontackt till kabel	0,000	1	0,0642	0,0080	0,252 (±34,8%)	1	0,2323	0,0913

Tabell 3.4: Ytaktivitet, betastrålare

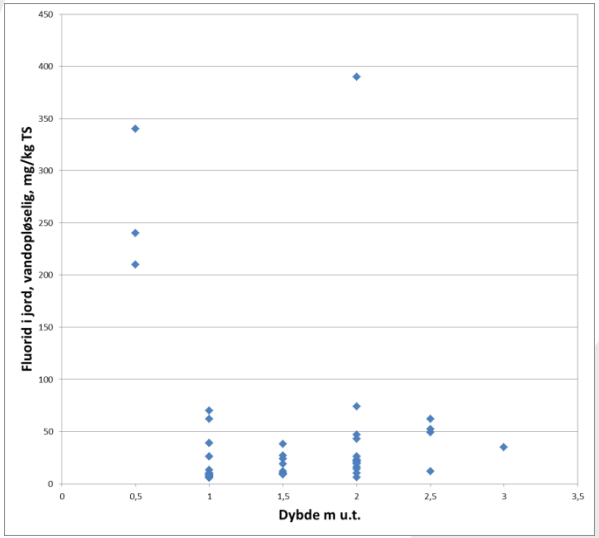
Nuklid	Ytaktivitet, 2 % ^{241}Am (Bq/m^2)	Ytaktivitet, 7,7 % ^{241}Am (Bq/m^2)
^{60}Co	1,11E+06	1,11E+06
^{137}Cs	9,69E+03	9,69E+03
^{14}C	7,68E+03	7,68E+03
^{36}Cl	5,23E+03	5,23E+03
^{55}Fe	2,33E+04	2,33E+04
^{63}Ni	5,32E+05	5,32E+05
^{154}Eu	9,66E+03	9,66E+03
^{155}Eu	7,31E+03	7,31E+03
^{90}Sr	6,54E+03	6,54E+03
^{99}Tc	1,85E+05	1,85E+05
^{134}Cs	2,98E+02	2,98E+02
^{241}Pu	2,52E+04	9,69E+04
Summa betastrålare	1,9E+06	2,0E+06

DANSK DEKOMMISSIONERING

Soil sampling



From radiological interest to conventional



DANSK DEKOMMISSIONERING

Clearance

Clearance is the removal of radioactive materials, buildings (and land areas) from regulatory control, which governs radioactive materials. Clearance is possible if the sum of ratios between activity concentrations (C_i^*) and the radionuclide specific clearance levels (CL_i) is below 1.

$$\sum_{i=1}^{N} \frac{C_i^*}{CL_i} < 1$$

$$\sum_{i=1}^{N} \frac{C_i}{CL_i} + 1.65 \cdot \sqrt{\sum_{i=1}^{N} \frac{u_i (C_i)^2}{CL_i^2}} < 1$$

DANSK DEKOMMISSIONERING

Clearance levels

Radionuclide	Mass-specific clearance levels (IAEA RS-G-1.7) [Bq/g]
^{55}Fe	1000
^{3}H, ^{41}Ca, ^{63}Ni	100
^{236}U, ^{241}Pu	10
^{14}C, ^{90}Sr, ^{109}Cd, ^{234}U, ^{235}U, ^{238}U	1
^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{154}Eu, All actinides but ^{241}Pu	0.1

DANSK DEKOMMISSIONERING

Clearance and scaling factors

Measurements on samples can establish conservative activity ratios (scaling factors) between radionuclides which are difficult to measure and a radionuclide (key nuclide) which is more easy to measure.

$$C_i = SF_{i,k} \cdot C_k$$

difficult-to-measure radionuclide *i*

scaling factor

easy-to-measure key radionuclide *k*

DANSK DEKOMMISSIONERING

Clearance and scaling factors

Hot Cell facility: 19 paint samples analysed and conservative activity ratios (scalings factors) extracted. ^{137}Cs is the key radionuclide

Nuclide	Scaling factor	Rel. standard uncertainty (%)
^{90}Sr	0.53	30
^{238}Pu	0.11	50
^{239}Pu	0.054	60
^{240}Pu	0.041	50
^{241}Pu	1.6	50
^{241}Am	0.093	35
^{242}Pu	0.00011	50
$^{243}Cm+^{244}Cm$	0.035	50
$^{242}Cm+^{242m}Am$	0.00077	50

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Clearance and scaling factors

Neutron irradiated materials:

$$SF_{i,k} = \frac{m_i \cdot A_k \cdot N_{F,i} \cdot \sigma_i \cdot \left(1 - e^{\frac{-\ln(2)\cdot\tau}{T_i}}\right) \cdot e^{\frac{-\ln(2)\cdot t}{T_i}}}{m_k \cdot A_i \cdot N_{F,k} \cdot \sigma_k \cdot \left(1 - e^{\frac{-\ln(2)\cdot\tau}{T_k}}\right) \cdot e^{\frac{-\ln(2)\cdot t}{T_k}}}$$

- m: relative mass content of mother
- A: atomic mass
- N_F: isotopic abundance of mother
- σ: neutron absorption cross section
- T: nuclide half-life
- τ: irradiation time
- t: time since stop of irradiation

Co	(+/-) 2s	Li	(+/-) 2s
ppb	ppb	ppb	ppb
4713	1000	22235	2395

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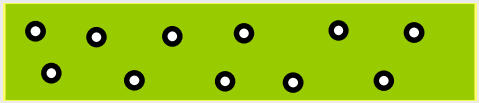
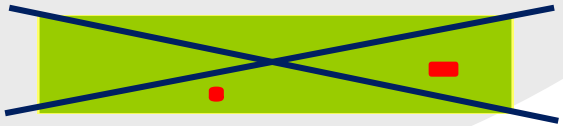
Clearance by sampling

$$\sum_{i=1}^{N} \frac{C_i}{CL_i} + 1.65 \cdot \sqrt{\sum_{i=1}^{N} \frac{u_i(C_i)^2}{CL_i^2}} < 1$$



Statistical test (sign-test) based on measured activity concentrations in samples. N



Clearance by sampling not possible when hot spots.

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Clearance by sampling

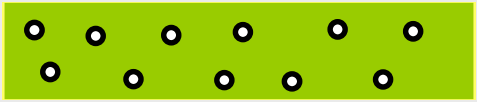
The outer part of the biological concrete shielding of the DR2 reactor was cleared by measuring on samples from drill cores

removal of cleared concrete

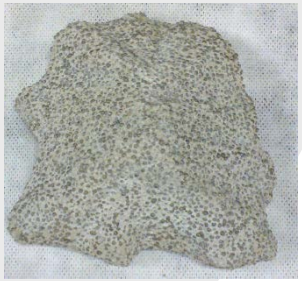
DANSK DEKOMMISSIONERING

Clearance by sampling

Spent fuel storage block iron ball concrete shielding contaminated with ^{14}C and ^{3}H



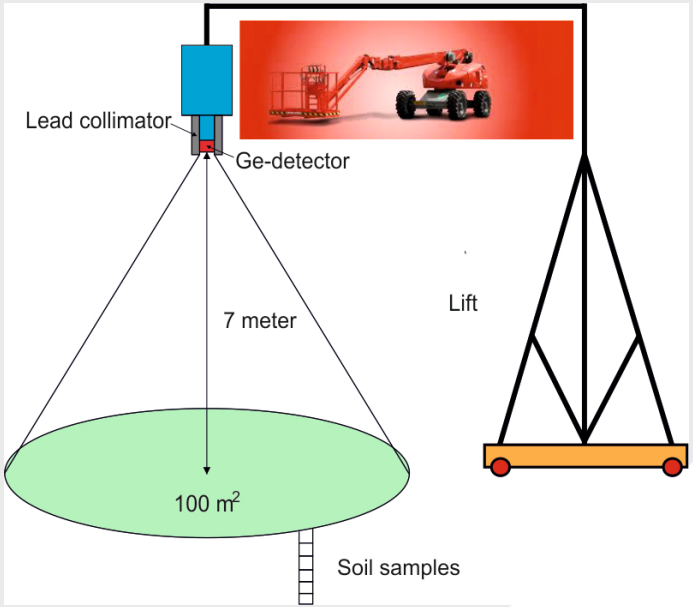
14 samples measured, 50 tons cleared



DANSK DEKOMMISSIONERING

Clearance by sampling

Land area measurements combined with soil measurements



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Samples and clearance

Sample material	Radionuclides except γ-emitters	Purpose
Paint	Fission products and actinides	Scaling factors
Paint	^{3}H, ^{14}C	Clearance
Concrete	^{3}H, ^{14}C, total β	Clearance
Iron	^{63}Ni, ^{55}Fe, Fe, Co, Ni	Clearance
Paper	U-234, U-235, U-238	Scaling factors
Water	^{3}H, ^{14}C	Clearance

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Conclusions

- Sampling is an integral part of all the phases of decommissioning work
- Purpose dictates the sampling method
- Different levels of uncertainty are required
- Radiochemical laboratory is a must for some analyses

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