Clearance of Decommissioning Waste by Measurements on Samples

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Clearance and clearance level (CL)

Clearance
is the removal of materials, buildings or land areas from nuclear regulatory control.

Clearance levels (CL's)
are radionuclide specific levels of activity concentration (mass specific or surface specific) below which, a contamination is regarded as 'of no concern'.

The Clearance Function

- Infrastructure for clearance measurements
- Comprises laboratory facilities, detectors, software for clearance calculations, personnel etc.
- Obtained accreditation in June 2007 according to ISO/IEC 17025:2005

In toto measurement or measurement by sampling

in toto measurement — detector, object

measurement by sampling — detector, sample

Clearance criteria

Only one nuclide: $\frac{C}{CL} < 1$

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

clear | hold

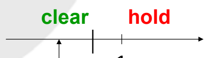
$\sum_{i=1}^{N} \frac{C_i}{CL_i}$ — 1

Clearance criterion
(in toto measurements)

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

Cm_i measured activity concentration of nuclide *i*

$u_i(Cm_i)$ uncertainty associated with Cm_i



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

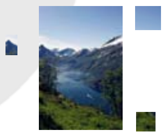
Critical level and scaled concentrations

If a radionuclide is expected to be an object, but no activity is detected, the critical level is used as concentration.

Concentration of a radionnuclide not measurable by a given detection method, can sometimes be calculated by scaling the activity concentration of another nuclide (key nuclide).

Measurements on samples (general comments)

- can be the only feasible one
- can reduce time and costs
- raises questions regarding representativity etc.
- add complexity

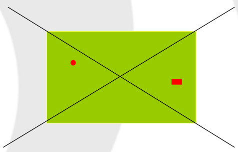


Measurements on samples (A and B)

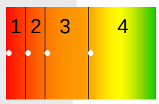
A-cases:
concentration vary but the relative variation is "known"

B-cases:
concentration is known to be almost homogeneous

Sampling for hot spots is not allowed!



A-cases (criterion)



$$\sum_{i=1}^{N} \frac{\frac{\sum_j Cm_{i,j} \cdot m_j}{\sum_j m_j}}{CL_i} + 1.65 \cdot \sqrt{\sum_{i=1}^{N} \frac{u\left(\frac{\sum_j Cm_{i,j} \cdot m_j}{\sum_j m_j}\right)^2}{CL_i^2}} < 1$$

A-case example

Sample/ region	Mass of region [kg]	^{60}Co conc. in sample [Bq/g]	^{60}Co conc. in object [Bq/g]	^{3}H conc. in sample [Bq/g]	^{3}H conc. in object [Bq/g]
1	400	0.012	0.026 ± 0.008	12	26 ± 12
2	200	0.022		22	
3	150	0.031		31	
4	100	0.080		80	

$$\frac{0.26}{0.1} + \frac{26}{100} + 1.65 \cdot \sqrt{\frac{0.008^2}{0.1^2} + \frac{12^2}{100^2}} = 0.76$$

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B-cases

Test if the hypothesis:

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

is false or true

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B-cases, Sign test

Recipe for the Sign test

1. Calculate *Y* and the associated uncertainty *u(Y)*

$$Y = \sum_{i=1}^{N} \frac{Cest_i}{CL_i} \qquad u(Y) = \sqrt{\sum_{i=1}^{N} \frac{u(Cest_i)^2}{CL_i^2}}$$

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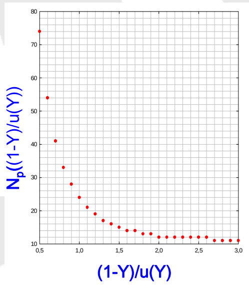
B-cases, Sign test

2. Calculate the minimum number of samples necessary to do the test



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B cases, Sign test

3. Take at least the minimum number of samples, measure and calculate Y_j-values, and the mean and standard deviation of these values

$$Y_j = \sum_{i=1}^{N} \frac{Cm_{i;j}}{CL_i}$$

4. Confirm the step 2 calculations or adjust the number of samples.

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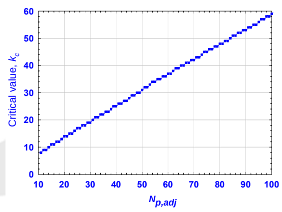
B-cases, Sign test

5. Find S+, which is the number of times Y_j's are < 1

6. Find the critical value, k_c



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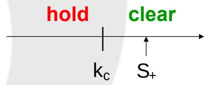
B-cases, Sign test

7. Compare *S+* with k_c



B-case example (pipe system)

^{3}H concentration: C_{H-3} ≈ 40 Bq/g (CL_{H-3} = 100 Bq/g)

uncertainty: $u(C_{H-3})$ ≈ 10 Bq/g

^{14}C concentration: C_{C-14} ≈ 0.3 Bq/g (CL_{C-14} = 1 Bq/g)

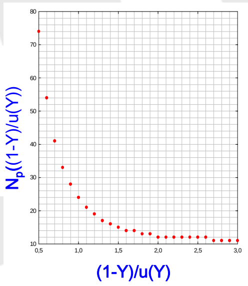
uncertainty: $u(C_{C-14})$ ≈ 0.15 Bq/g

$$Y = \frac{40}{100} + \frac{0.3}{1} = 0.7 \qquad u(Y) = \sqrt{\left(\frac{10}{100}\right)^2 + \left(\frac{0.15}{1}\right)^2} = 0.2$$

$$\frac{1 - Y}{u(Y)} = 1.5 \longrightarrow N_p = 15 \longrightarrow k_c = 10$$

B-cases, Sign test

2. Calculate the minimum number of samples necessary to do the test



B–case example

Sample	^{3}H conc. [Bq/g]	^{14}C conc. [Bq/g]	Y_j
1	35	0.21	0.56
2	37	0.23	0.60
3	35	0.27	0.62
4	41	0.24	0.65
5	45	0.65	1.10
6	55	0.49	0.80
7	27	0.26	0.60
8	35	0.24	0.85
9	41	0.27	0.68
10	32	0.22	0.54
11	42	0.25	0.67
12	37	0.10	0.47
13	30	0.15	0.45
14	55	0.45	1.00
15	27	0.20	0.47
Mean concentration ± standard uncertainty	38 ± 9	0.27 ± 0.13	0.65 ± 0.19

S_+= 13 i.e. clearance

Amount of material cleared by sampling so far.

DR 1: 100 tons (A-cases)

DR 2: 250 tons (A-cases)

DR 3: 480 tons (A-cases+ B-case)

Thank you for your attention!