Validation of the clearance methodology

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To clear or not to clear, BVS-ABR, 11 september 2015, Brussels

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two cases - two questions

- Case 1: World Record 400 m freestyle swimming in an Olympic Swimming pool (length: 50 m)
  - Ian Thorpe (Manchester, 2002): 3:40.08
  - Paul Biedermann (Rome, 2009): 3:40.07
  - Question? Is the World Record valid?

- Case 2: “To clear or not to clear?”
  - Analysis result from gamma spectroscopy: $A_{Co\text{-}60} = 10\ Bq.g^{-1}$
  - Question: Should the object be considered as radioactive waste or can the object be unconditionally released?

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Validation of the clearance methodology outline

- Radiological protection criterion & operational alarm level(s)
- Main validation parameters – detection limit
- 100%, 2 x 100%, sampling & statistics
- Straightforward examples
- Concluding remarks

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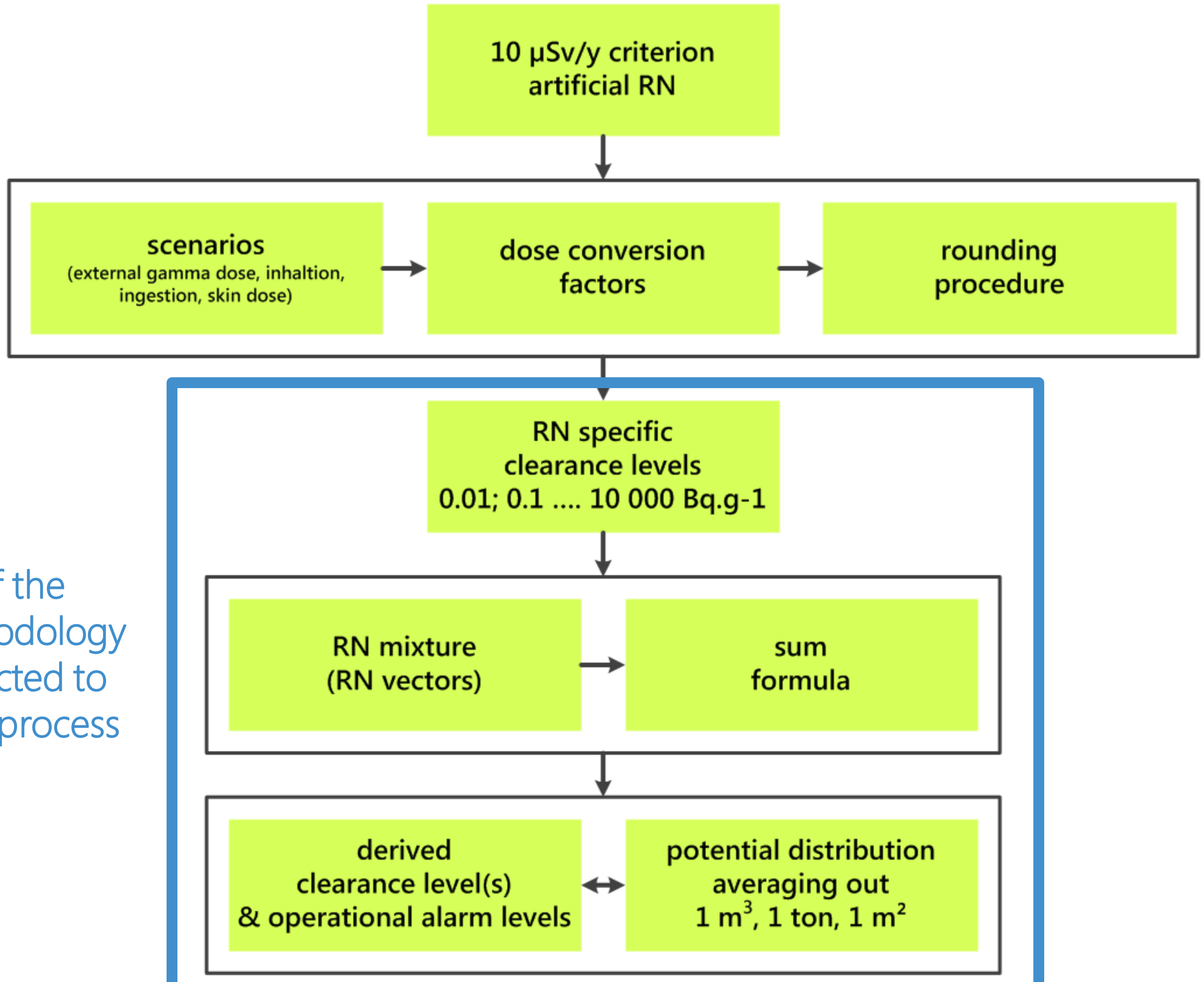
From a radiological protection criterion towards operational alarm levels: simplified scheme



Validation of the clearance methodology is usually restricted to this part of the process

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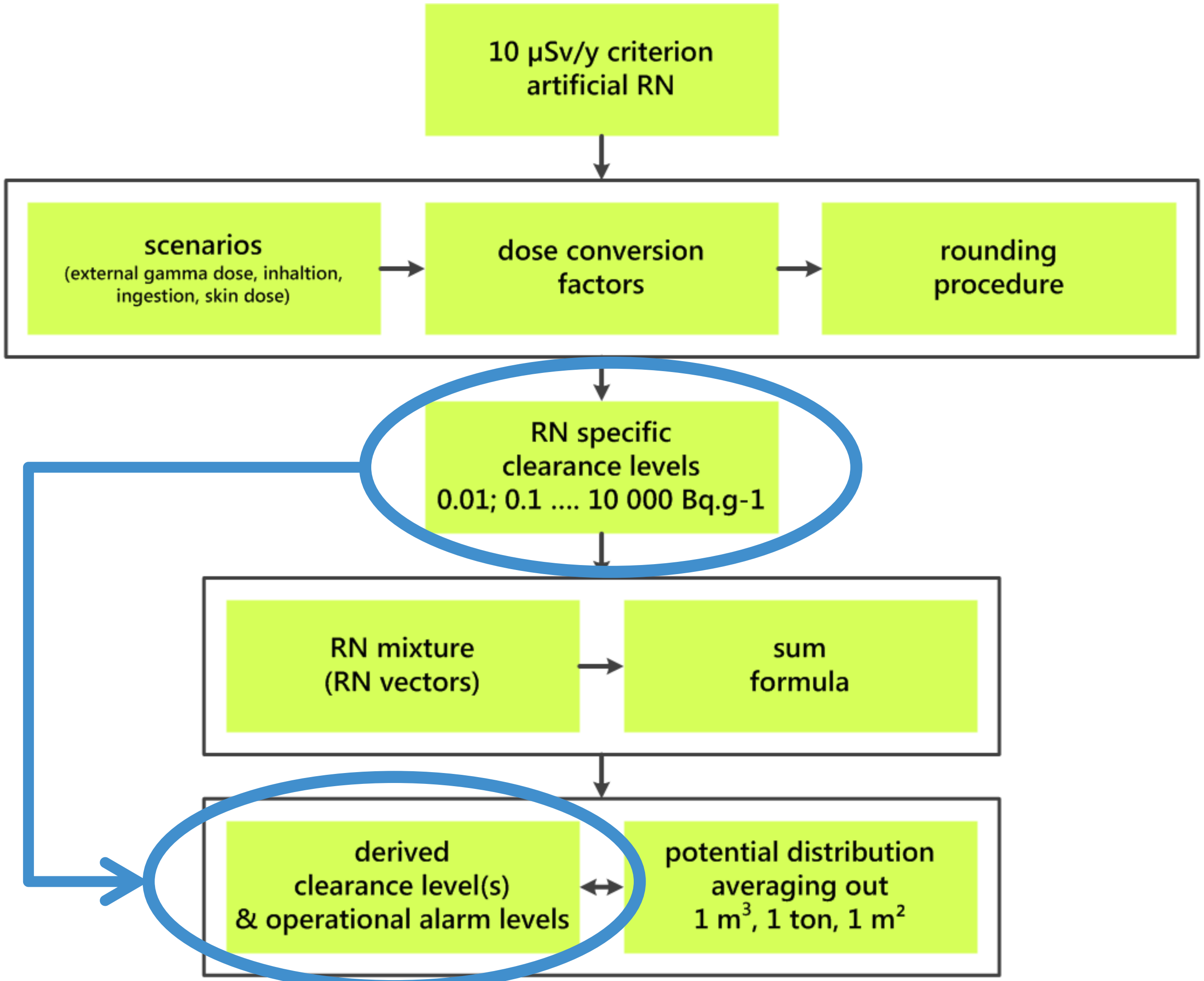
From specific clearance levels to derived clearance & operational alarm levels



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From specific clearance levels to derived clearance & operational alarm levels

- First step in characterization = historical assessment
  - what radionuclides could be present
  - activation/contamination
  - potential levels & distribution

- In practice we usually have a mixture of radionuclides, therefore: application of the "sum formula"
  - $\sum_j \frac{C_j}{C_{j,L}} \leq 1$
  - Cj = specific activity of RN j present in the material
  - Cj,L = clearance level

- A clearance methodology is usually based on radiological measurements

From specific clearance levels to derived clearance & operational alarm levels

- Depending on the nuclide mixture and the radiological properties of the most important radionuclides (potentially) being present, most clearance methodologies are based on:
  - Total γ
  - γ spectroscopy
  - Total $\beta(\gamma)$
  - Total α

- Converting a clearance level into a derived clearance level and operational alarm level (maximum allowed signal of the measurement equipment) is usually conservative, e.g.
  - Main RN Co-60 (CL=0,1 $Bq.g^{-1}$) & Cs-137 (CL=1 $Bq.g^{-1}$)
  - Equipment used = large surface area plastic scintillator detectors
  - Operational alarm level is based on Co-60

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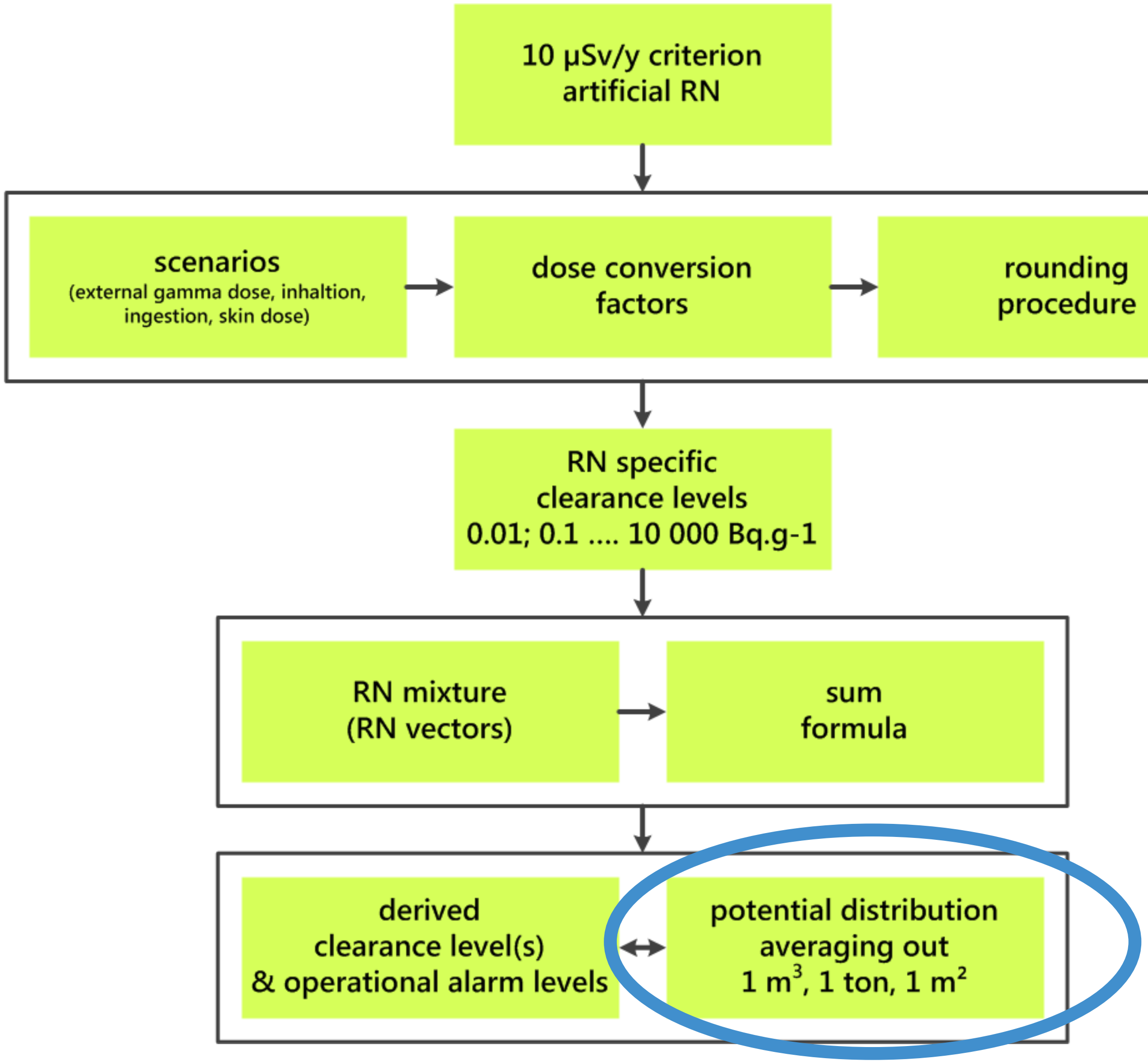
Averaging out



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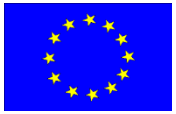
Averaging out
FANC Decision on clearance 2010 & EC RP113

Solid materials

- To prevent unwanted dilution, the determination of the activity concentration needs to be performed on a maximum amount of 1 ton and 1 m^3. For practical cases the levels need to be considered as average values for a measured entity.



Buildings & Building rubble

- The measurement procedure, including the averaging area and mass, should take into account the type of nuclear facility, the material to be cleared and the radionuclides involved. In general, an averaging quantity of 1 Mg for mass specific and an averaging area of 1 m^2 for surface specific clearance levels may be appropriate.

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Averaging out
examples of current practices

- Surface contamination measurements using a hand held detector
  - Alarm level based on efficiency of the most conservative radionuclide and application of a limit value of 0,4 Bq.cm^{-2} (β/γ)
  - Averaging out surface: 0,01 m^2 up to 0,06 m^2 (vs. 1 m^2)

- Gamma spectroscopy on 200-L barrels (vs. 1 m^3)
  - Most conservative activity distribution
  - Combination of surface contamination hotspot measurement and total gamma measurement of each 20 kg (vs 1 ton)

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Method validation
Why & how?

- FANC decision on clearance 2010: verification that the detection limit of the measurement equipment < operational clearance/alarm level
- fitness for purpose
- in "normal use" we need to know
  - the uncertainty associated with the results
  - individual influence factors in relation to the overall performance

- investigate individual sources of error or uncertainty
  - only when significant compared to the overall precision measures in use
- determine overall method performance parameters during
  - method development • in-house validation protocols • interlaboratory study

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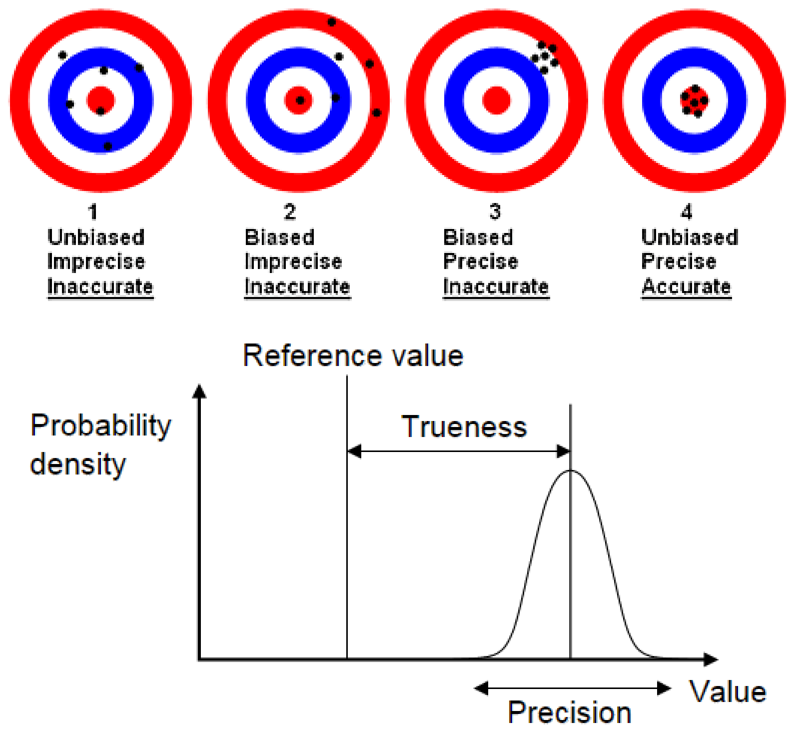
Method validation
Main validation parameters

- trueness (bias), precision & accuracy (ISO 5725:2008)



According to ISO 5725-1, Accuracy consists of Trueness (proximity of measurement results to the true value) and Precision (repeatability or reproducibility of the measurement)

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Method validation
Main validation parameters

- Linearity
  - response to a range of values/concentrations
  - example: potential linearity problem at high or low concentration ranges

- Robustness or ruggedness
  - effect of changes in one or more parameter (interference)
  - example: temperature

- Selectivity
  - degree to which a method responds uniquely to the required analyte
  - Example: effect on the Cs-137 determination using gamma spectroscopy when Co-60 concentration changes

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Method validation
Main validation parameters

- Decision threshold & detection limit (most important validation parameter for release measurements)

Organisation	L_C	L_D
ANSI (American National Standards Institute)	Critical Level (CL)	Lower Limit of Detection (LLD)
ACS (Amercian Chemical Society)	Limit of Detection (LOD)	Limit of Quantification (LOQ)
IUPAC (International Union of Pure and Applied Chemistry)	Detection Decisions (LC)	Minimum Detectable Value or Detection Limit (LD)
ISO 11929:2010	Decision Threshold (y*)	Detection Limit (y#)

value of the estimator of the measurand, which when exceeded by the result of an actual measurement using a given measurement procedure of a measurand quantifying a physical effect, one decides that the physical effect is present

smallest true value of the measurand which ensures a specified probability of being detectable by the measurement procedure

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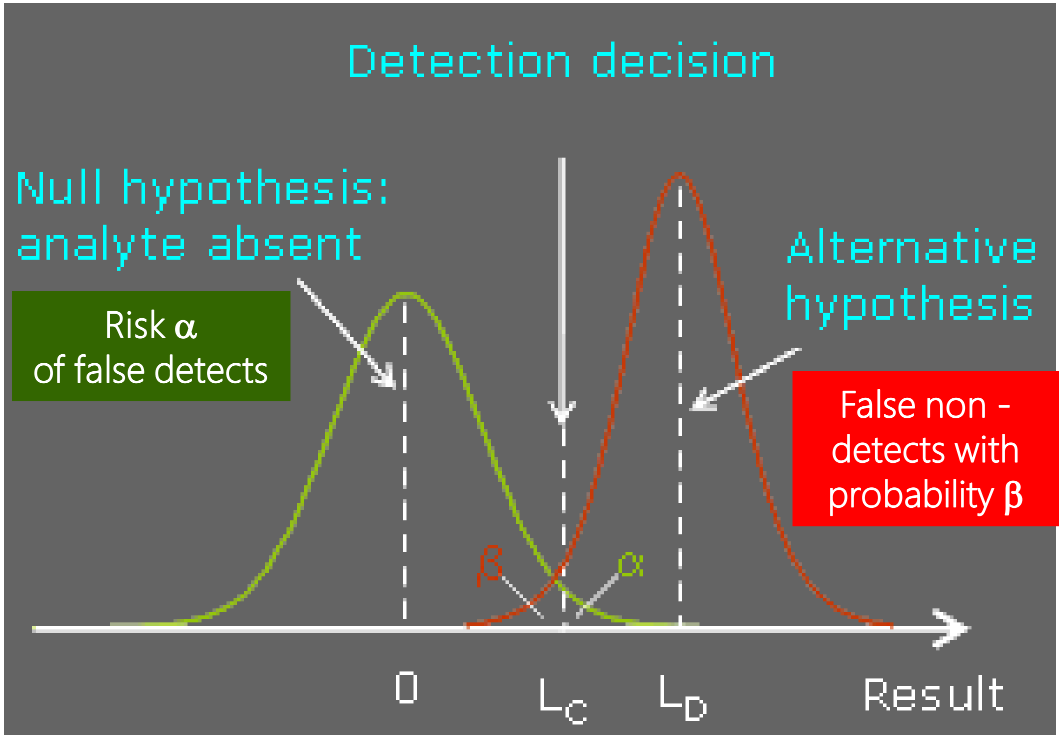
Method validation
Main validation parameters



ISO 11929:2010

- the "decision threshold" gives a decision on whether or not the physical effect quantified by the measurand is present
- the "detection limit" indicates the smallest true value of the measurand which can still be detected with the applied measurement procedure; this gives a decision on whether or not the measurement procedure satisfies the requirements and is therefore suitable for the intended measurement purpose
- the "limits of the confidence interval" enclose, in the case of the physical effect recognized as present, a confidence interval containing the true value of the measurand with a specified probability

- Decision threshold & detection limit for a hand held detector (beta/gamma channel) according to ISO 11929 (2000)

η		20%		
$k_{1-\alpha}$		1,64		
$k_{1-\beta}$		1,64		
R_0 (cps)		10		
t_0 (s)		120		
S (cm^2)		100		
t_b (s)	Decision threshold cps	Detection limit cps	Decision threshold Bq/cm^2	Detection limit Bq/cm^2
1	5,2	13,2	0,26	0,66
3	3,1	7,0	0,15	0,35
5	2,4	5,3	0,12	0,27
10	1,7	3,7	0,09	0,19
30	1,1	2,2	0,05	0,11

Remarks:

- Detection limit should be < clearance level (minimum 3 s measurement in case of CL = 0,4 $Bq.cm^{-2}$)
- In many cases the detection limit is about twice the decision threshold
- Applying $k_{1-\alpha}$ = 1,64: still 5% false positives (exceeding decision threshold)
- The background should be stable

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FANC decision on clearance 2010: general rule two independent measurements have to be applied

Release of solid wastes originating from a class I, II or III installation

- Independent measurements can consist of
  - Two consecutive measurements of a batch using the same measurement method by two different operators (potentially using the same detector); or
  - Two measurements based on the different measurement methods (potentially by the same operator)
- Whenever the reliability and the reproducibility of clearance measurements is strongly depending on the measurement conditions, one can not deviate from this general rule
- One can deviate from the general rule in case the clearance procedure shows that a second measurements has a limited additional value

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Clearance practices during operational phase & during decommissioning

- Operational phase: limited amounts
  - Mainly material streams of auxiliary equipment that have been in use in the controlled area for a limited period of time

- Decommissioning phase: large amounts
  - Installation
  - Building(s)
  - Site

- NEA/RWM/WPDD(2005)10 regarding site release:
  - There is general consensus that measurements for site release/clearance need not cover the entire surface. A reasonable measurement density needs to be derived from statistical considerations.
  - Furthermore, the measurement density will also depend on the category of the surface, i.e. the contamination class. Such a categorization of sites according to their probability for contamination has been used in many decommissioning projects

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Sampling & statistical methods

- There is a need to use statistical methods to study the appropriate sampling which guarantees an acceptable level of representativeness of results, i.e., to assist in the determination of the sampling strategy according to acceptable levels of uncertainty.

- There is a particular importance when the homogeneity of the materials under study can not be guaranteed, i.e., the homogeneity of the material itself and the homogeneity of the activity distribution.

- The measurements implemented on the samples are generally used to obtain information about the activity distribution in the material as a whole for a decision on whether the material complies with the clearance criteria or not.

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Sampling & statistical methods

- Increasing the number of samples gives a better estimation of the median value and the standard deviation of the activity (surface or mass) values in the material.

- The minimum number of samples needed to make a statistical compliance test depends on the median value and the standard deviation of the activity, the statistical test used and the levels put on the decision errors that are used in the test (confidence level).

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Sampling & statistical methods

- MARSSIM
  - Non-parametric tests (Sign test, WRS - Wilcoxon Rank Sum test)
- DIN 25457-6 (annex B)
  - Statistical tests based on normal distribution
- France
  - Pre-treatment survey: Geostatistical modeling
  - Final control measurements: various methods are being used
    - MARSSIM
    - ISO TR8550
    - Theory of sampling (Gy, Pitard)

Judgmental vs systematic approach

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Various clearance measurement methods for PWR building release: some options

- Option A: total β(γ) using a hand held detector
  - Transport regulation: total β < 0,4 $Bq.cm^{-2}$
  - Operational alarm level: net count rate < 10 cps
  - 2 x 100% (wo different operators)
- Option B = In-situ gamma spectroscopy
  - RP113 (10 µSv/y criterion)
  - Clearance level: Σ(Co-60+Cs-137) < 10000 $Bq.m^{-2}$
  - Only 1 measurement: second measurement has limited additional value
- Option C = Gamma spectroscopy of a 200-L drum with shaved painting
  - ARBIS
  - Clearance level: Σ(Co-60/0,1+Cs-137/1) < 1 (concentrations in $Bq.g^{-1}$)
  - Only 1 measurement: second measurement has limited additional value

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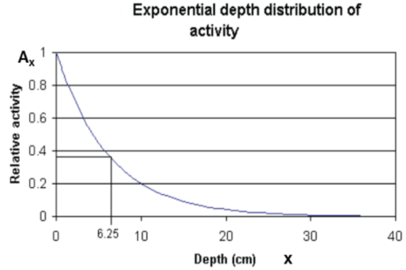
Various clearance measurement methods for PWR building release: which one is most conservative?

- Option A = total β using a hand held detector
  - Transport regulation: total β < 0,4 $Bq.cm^{-2}$ (**4000** $Bq.m^{-2}$)
  - Operational alarm level: net count rate < 10 cps
- Option B = In-situ gamma spectroscopy
  - RP113 (10 µSv/y criterion)
  - Clearnace level: Σ(Co-60+Cs-137) < **10000** $Bq.m^{-2}$

In case of previous contamination in the mass of the building materials it is easily possible that the total β measurement will pass the control measurements but not the In-situ gamma spectroscopy measurement



Various clearance measurement methods for PWR building release: release of dust from shaving?

- Option C = Gamma spectroscopy of a 200-L drum with shaved painting
  - ARBIS
  - Clearance level: Σ(Co-60/0,1+Cs-137/1) < 1 (concentrations in $Bq.g^{-1}$)
  - Only 1 measurement: second measurement has limited additional value

Suppose we have surface contamination sometimes exceeding 0,4 $Bq.cm^2$ (only Cs-137, option A) and decide to remove the painting

- Average contamination is 0,4 $Bq.cm^{-2}$ or 4000 $Bq.m^{-2}$
- Surface = 40 m^2; 160 kBq Cs-137
- Average depth of removal = 5 mm; 200-L or 240 kg
- Gamma spectroscopy on 200-L drum: average Cs-137 concentration = 0,7 $Bq.g^{-1}$

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Validation of the clearance methodology

- Every interpretation of a measurement result requires the use of statistics, even if we measure 100% of the surface/mass of materials to be released

- Measuring an item and applying ISO 11929 in a strict sense:
  - Only decision OK or NOK
  - Uncertainty on the actual result might be large (the goal is not to determine the concentration)

- The validation parameter “detection limit” is important in view of release measurements, but its importance
  - should not be over exaggerated
  - is one uncertainty parameter in a full process

Validation of the clearance methodology

- Harmonization of methodologies is nice but
  - Does not mean that a standard procedure is existing that can be used at any time
  - One should know and understand the complete process and use common sense

- Clearance in practice is in many cases much more restrictive than the 10 μSv/y criterion

two cases - two questions

- Case 1: World Record 400 m freestyle swimming in an Olympic Swimming pool (length: 50 m)
  - Ian Thorpe (Manchester, 2002): 3:40.08
  - Paul Biedermann (Rome, 2009): 3:40.07
  - Question: Is the World Record valid?
    - Tolerance 50 m according to FINA (International Swimming Federation): 3 cm
    - 8 (400 m/50 m) x 3 cm = 24 cm @ speed of 0.55 m/s: 0.13 s!

- Case 2: "To clear or not to clear?"
  - Analysis result from gamma spectroscopy: $A_{Co\text{-}60} = 10\ Bq.g^{-1}$
  - Question: Should the object be considered as radioactive waste or can the object be unconditionally released?

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