IRPA 2018 Refresher course "NORM characterization and applied metrology"

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Content

- Aim and learning objectives
- Regulations
- NORM characterization and applied metrology
- Intercomparison of instruments and methods for NORM
- Summary

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Aim

The aim of the refresher course is to provide participants an overview of the applicability of instruments and methods for the radiological characterization of "natural occurring radioactivity (NOR)" in materials and of elevated radiation levels caused by this NOR in daily routine, in order to assess:

Learning objectives

- Instruments and methods that can be applied in daily routine to prove to be in compliance with National regulations based on EC 2013/59/EURATOM;
- Elevated radiological health risks and to assist in the decision making process to take adequate measures;
- The level of the radiological contamination/concentration of materials (e.g. materials to be processed, products and residues).

NORM characterization and applied metrology

Introduction

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Expect that you have knowledge of ….. and experience in …..

- Knowledge of …
  - European directive EC 2013/59/EURATOM (EC 1996/29/EURATOM)
  - Hand-held monitors e.g. contamination and dose rate
  - Gamma spectrometry
  - NOR nuclides and their eventual decay chains
  - Statistics
- Experience in ...
  - Applying/ working with above instruments
  - Interpretation of collected data

Out of scope

- Detection principles
- How to operate (specific) instruments
- Information about a specific instrument

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Part 1: Regulations

Historical overview "NORM in EC-directives"

EC Council Directive	Exception Activity [Bq/g]	NOR	Remarks
20-2-1959/EURATOM	$\Sigma_i (C_{i(artificial)}) \leq 100$	-	NPP - ^{238}U, ^{235}U
80/836/EURATOM	$\Sigma_i (C_{i(artificial)}) \leq 100$	-	NPP - ^{238}U, ^{235}U; radon
1996/29/EURATOM	$\Sigma_i (C_{i(art\ \&\ NOR)}/C_{Ei(art\ \&NOR}) \leq 1$	x	Definition of Nat. Occ. Radionuclides, weighted sum
2013/59/EURATOM	$\Sigma_i (C_{i(artificial)}/C_{Ei(artifical}) \leq 1$		Artificial radionuclides
	$C_{i(natural}/C_{Ei(natural)} \leq 1$	x	Natural Occ. Radionuclides (NOR)
	^{226}Ra/300 Bq/kg + ^{232}Th/200 Bq/kg + ^{40}K/3000 Bq/kg ≤ 1	x	NOR in construction materials

Historical overview "NORM in EC-directives" construction materials

- 2013/59/EURATOM

  Index method: $I = A_{Ra226}/300 + A_{Th232}/200 + A_{K40}/3000$ [Bq/kg]

- Additional approved methods in the national regulations of the Netherlands

  1 CEN-method. The technical body CEN/TC-351 of the "Comité Européan de Normalisation (CEN) has worked out a method calculating the increase of the effective dose (D), see formula below, by the emitted gamma radiation of construction materials.

$$D = \{[281+16{,}3\rho d-0{,}0161(\rho d)^2] \times a_1 + [319+18{,}5\rho d-0{,}0178(\rho d)^2] \times a_2 + [22{,}3+1{,}28\rho d-0{,}00114(\rho d)^2] \times a3\} \times 10^{-6} - 0{,}29 \text{ mSv / jaar}$$

  Herein is: $a_1 = {}^{226}Ra$, $a_2 = {}^{232}Th$, $a_3 = {}^{40}K$ the activity concentration in [Bq/kg]. The thickness d [m] has a fixed value of 0,2 m and the density ρ [kg/m^3] has a minimum value of 300 kg/m^3.

Historical overview "NORM in EC-directives" construction materials (continued)

- Additional approved methods in the national regulations of the Netherlands

  2 Weighted sum of the activity concentrations of the primordial nuclides ^{226}Ra, ^{232}Th and ^{40}K (see formula below).

$$\Sigma = a_1/1.000\ Bq/kg + a_2/1.000\ Bq/kg + a_3/10.000\ Bq/kg$$

Herein is: a_1 = ^{226}Ra, a_2 = ^{232}Th, a_3 = ^{40}K the activity concentration in [Bq/kg].

Historical overview "NORM in EC-directives"

The regulation on surface contamination in EC 1996/29/EURATOM has not been changed in the new directive EC 2013/59/EURATOM.

National regulations of the Netherlands

"For objects without substantial content with surface contamination only that surface contamination needs to be determined and tested against the exemption limit of 4 Becquerel/cm2 beta activity [ANVS-2018/137, Art 3.17]".

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Primordial radionuclides or natural occurring radionuclides

Most known:

^{238}U, ^{235}U, ^{232}Th and ^{40}K

But also:

^{87}Rb, ^{113}Cd, ^{115}In, ^{138}La, ^{147}Sm, ^{152}Gd, ^{176}Lu, ^{187}Re and ^{190}Ps [1]

[1] Regeling van de Staatssecretaris van Infrastructuur en Waterstaat, de Staatssecretaris van Sociale Zaken en Werkgelegenheid en de Minister voor Medische Zorg van 9 januari 2018, nr. IENM/BSK-2017/291098, houdende vaststelling van nadere regels ter bescherming van personen tegen de gevaren van blootstelling aan ioniserende straling (Regeling basisveiligheidsnormen stralingsbescherming)

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Natural radionuclides in soil (Bq/g) [IAEA SRS-44; Table 11]

Region / Country	^{238}U mean(range)	^{236}Ra mean(range)	^{232}Th mean(range)	^{40}K mean(range)
Egypt	0.037(0.002-0.11)	0.017(0.005-0.064)	0.018(0.002-0.096)	0.32(0.029-0.65)
USA	0.035(0.004-0.14)	0.040(0.008-0.16)	0.035(0.004-0.13)	0.37(0.10-0.70)
China	0.033(0.002-0.69)	0.032(0.003-0.69)	0.041(0.001-0.36)	0.44(0.009-1.80)
Japan	0.029(0.002-0.059)	0.033(0.006-0.098)	0.028(0.002-0.088)	0.31(0.015-0.990)
Syria	0.023(0.10-0.064)	0.020(0.013-0.032)	0.020(0.01-0.032)	0.27(0.087-0.78)
Ireland	0.037(0.008-0.12)	0.060(0.01-0.20)	0.026(0.007-0.07)	0.35(0.04-0.80)
Russia	0.019(0-0.067)	0.027(0.001-0.076)	0.030(0.002-0.079)	0.52(0.10-1.40)
Median	0.035(0.016-0.11)	0.035(0.017-0.06)	0.030(0.011-0.064)	0.40(0.140-0.085)

Natural radionuclides in ores and raw material (Bq/g) [IAEA SRS-44; Table 12]

Ore/mineral sand	^{238}U (series)	^{232}Th (series)
Phosphate ore	0.2-1,5	0.02
Monazite	6-40	8-300
Rutile	3.8	0.56
Tin ore (cassiterite)	1	0.3
Zirconium sand	0.2-74	0.4-40
Bauxite	0.4-0.6	0.3-0.4
Coal	0.01-0.025	0.01-0.025

Natural radionuclides in industrial residues and wastes (Bq/g) [IAEA SRS-44; Table 13]

	^{238}U	^{226}Ra	^{232}Th (series)
Tin ore (cassiterite)	1	1000-2000	4
Oil scale		1-1000	
TiO2 production from ilmenite		Up to 400	Up to 1500 (scale)
Monazite processing residues		Up to 450	3000
Aluminum processing sludge	260-540	150-330	
Fly dust	0.4		0.2
Blast furnace slag from steel production	0.15		0.15

Question: Has regulations influenced metrologies to characterize radioactive materials, due to the decrease of nuclide specific exemption and clearance levels?

YES

Examples:

- Expanding the data collection time (e.g. decreasing MDA)
- Expanding the “energy-range” (e.g. detection of ^{241}Am, ^{125}I, ^{129}I, etc.)
- Detectors e.g. P- & N-type HPGe (e.g. low background, electrical cool)
- Calibration procedures by software instead of by experiments (e.g. density, decommissioning and dismantling, characterization of waste)
- New instruments (e.g. scrap-monitors, isotope-indentifiers)

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Question: Has regulations lead to special metrologies for the characterization of primordial nuclides in materials produced in the Non-Nuclear industry?

NO

Reasoning:

- Observing the “historical” development in metrologies and instruments for the characterization of radioactive materials as well from the surface contamination, they are “in principle” driven by the nuclear industry
- Characterization of materials that might contain elevated concentrations of primordial radionuclides are performed in general by specialized lab’s and not by the Non-Nuclear industry.

Summary/Discussion

- Artificial radionuclides as well as natural occurring radionuclides are separately regulated in EC Directive 2013/59/EURATOM
- The analysis report should contain information about the concentrations of artificial – as well of the natural occurring radioactivity present in the material.
- For mixtures of artificial radionuclides, the weighted sum of nuclide-specific activities or concentrations (for various radionuclides contained in the same matrix) divided by the corresponding exemption value shall be less than unity.

$$\sum_{i=1}^{n} \left(\frac{C_i}{C_{E,i}} \right) \leq 1$$

C_i activity concentration in (Bq/g) of a radionuclide of artificial origin in the material

$C_{E,I}$ exempted activity concentration value for the radionuclide of artificial origin in that material

Summary/Discussion (continued)

- For natural occurring radionuclides all $C_{i(natural)}$ (concentration in Bq/g) divided by corresponding exemption value shall be less than unity. For those materials in secular equilibrium, it is the concentration of the parent nuclide.

$$\left(\frac{C_{i(natural)}}{C_{E,i(natural)}}\right) \leq 1$$

$C_{i\,(natural)}$ activity concentration in (Bq/g) of a radionuclide of natural origin in the material

$C_{E,i(natural)}$ exempted activity concentration value for the radionuclide of natural origin in that material

- Characterization instruments and methodologies for the radiological characterization of materials are historical driven by the nuclear industry

Summary/Discussion (continued)

- Dedicated instruments and methodologies should be developed for the Non-Nuclear industry, so that they will be able to apply these in daily routine. The advantage for the industry will be:
  - Optimizing measures in relation to sustainability (circular economy) as information will be available when needed (anticipating of the today's social trend *"I-Want-It-Now: I-WIN"*)
  - Optimization of the maintenance of installations e.g. in less time, thus decreasing maintenance costs
  - Realizing a cost reduction on their analyzing costs

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Finalized: Part 1: Regulations

Questions ?

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Part 2: I-Want-It-Now (I-WIN)

Example of a measuring methodology applicable for detecting elevated radiation levels by hand-held instruments

Example for determining the ^{226}Ra activity concentration in NOR by gamma-spectroscopy

How to anticipate with existing Hand-Held instruments as good as possible on I-WIN?

- It is an example of a method
- The methodology will be explained with the aid of a β-contamination data set
- The methodology takes into account:
  - The time-constant (σ) of the H-H instrument
  - The background radiation
  - The elevated radiation level. In the case of NOR it is expected (as example) that elevated levels are sometimes 0.25 times or less of the background
  - The methodology will be explained with figures

Time constant (σ)

Definition: It is a measure of the speed at which an instrument responds to a disturbance (here an elevated or a decreased radiation level).

The smaller this value, the sooner the value of the steady state will be reached.

By viewing the time that an instrument reaches a stable count rate, one can assess an approximation for the time constant of an instrument (often it is also specified by the manufacturer). In five times the standard deviation the measured signal will be stable (> 99%).

In the example it is assumed that the time constant (σ) of the instrument is 10 s.

NORM characterization and applied metrology

Part 2: I-Want-It-Now, Hand-Held monitor

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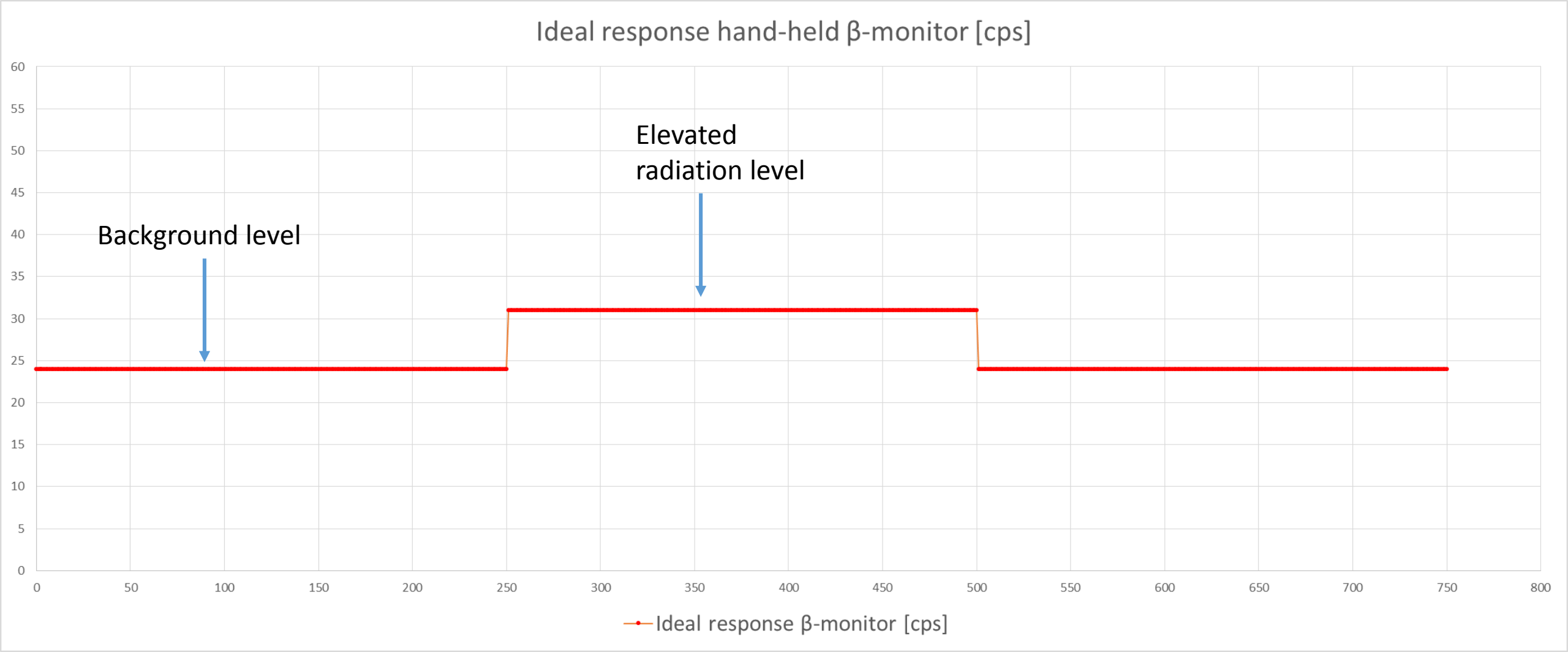

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Part 2: I-Want-It-Now, Hand-Held monitor

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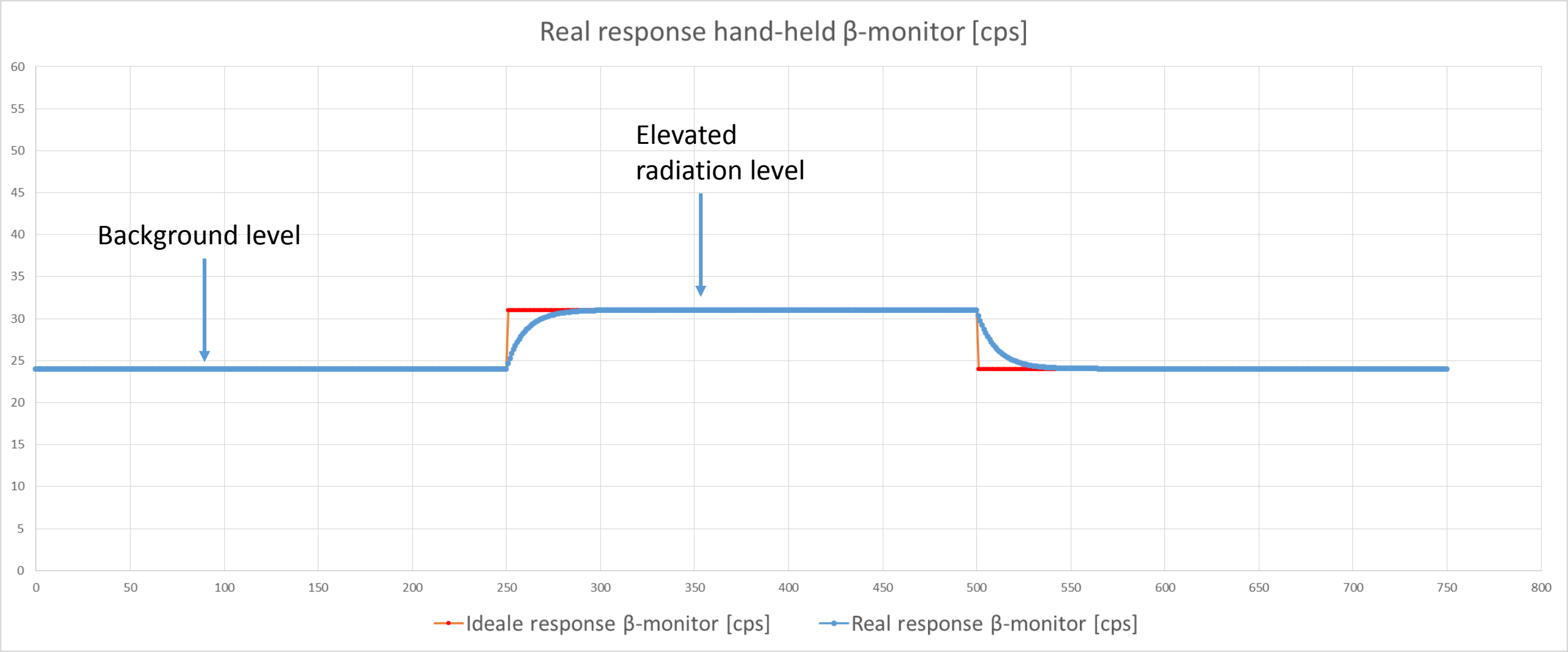

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Part 2: I-Want-It-Now, Hand-Held monitor

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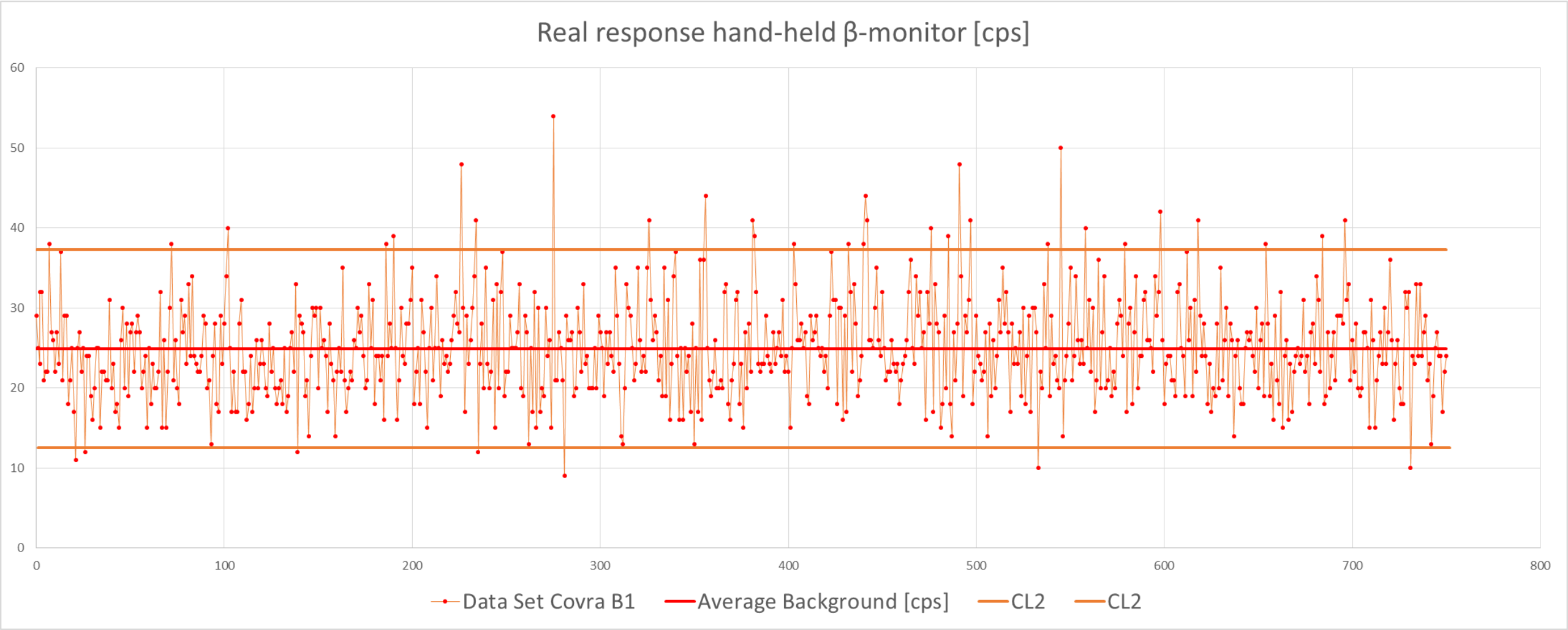

NORM characterization and applied metrology

Part 2: I-Want-It-Now, Hand-Held monitor

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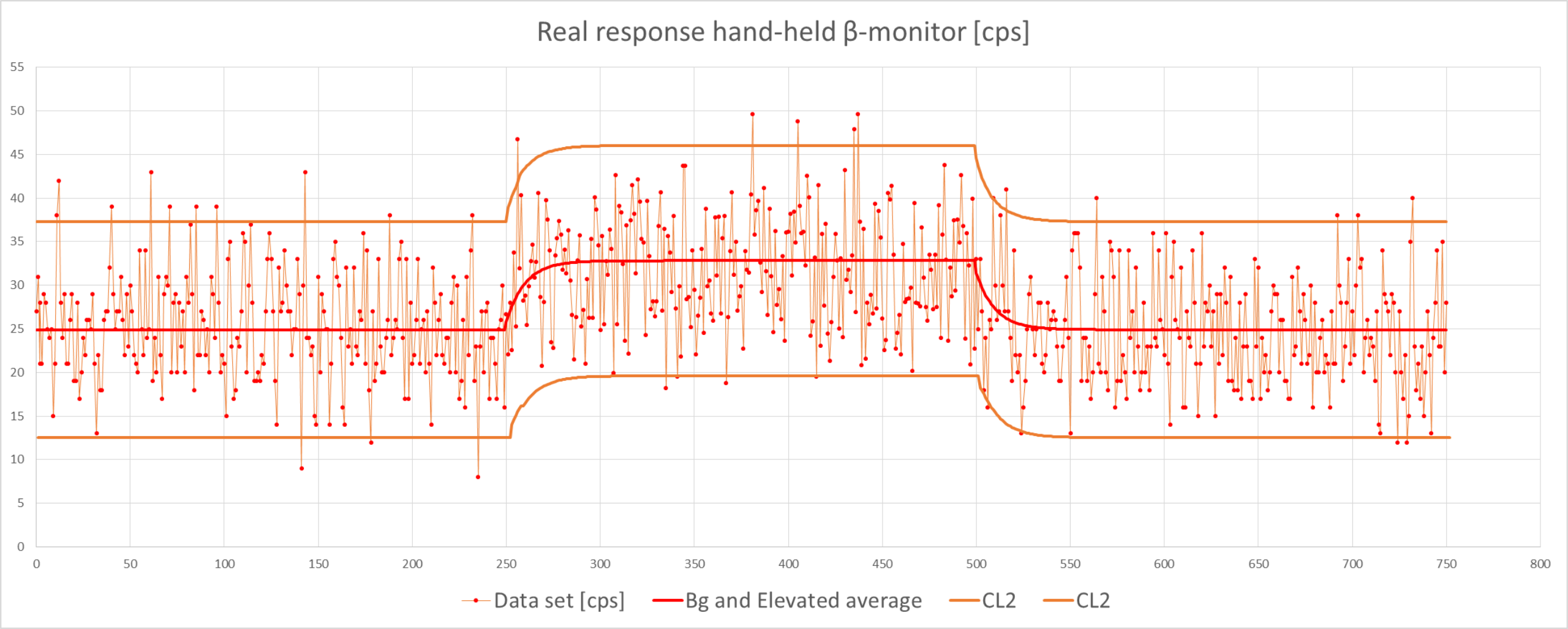

Conclusion/discussion

- The lower (in favor of the higher) measured values can be used as an indicator for observing changes in detected radiation levels
  - The disappearance of the lowest detected values is an indication that the radiation level is increasing
  - The appearance of lower values is an indication that the radiation level is decreasing (e.g. leaving an area with an elevated radiation level)
- The (assessed) average of the measured values can be used as a good assessment (best practices) of the radiation level present at that specific location.
- This method allows the use of faster time-constants, resulting that data will be available faster and thus measures or follow-up actions can be taken in due time, without a negative influence on the quality of the work

Finalized: Part 2: I-Want-It-Now; Hand-Held monitor

Questions ?

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How to anticipate with ^{226}Ra activity concentration determination with existing γ-spectroscopy systems as good as possible on I-WIN?

- The accurate determination of the ^{226}Ra activity concentration becomes more and more important as this nuclide like ^{232}Th and ^{40}K are explicitly mentioned in the EC 2013/59/EURATOM and national legislations for construction materials

- A correct determination of the ^{226}Ra activity concentration according to leading/best practices might cause that NOR residues can be recycled and/or reused instead of to be declared as notifiable NOR waste.

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Part 2: I-Want-It-Now, ^{226}Ra activity concentration

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- The radionuclide ^{226}Ra emits only one γ at 186.21 keV (fa = 0,0359).

- Other NOR nuclides interfering this energy line are:
  - ^{235}U at 185.72 keV (fa = 0,572). As both ^{238}U and ^{235}U are in secular equilibrium, in such a case ^{235}U will contribute for 42.5% to the net area counts of the 186 keV peak
  - ^{234}Pa at 186,15 keV (fa = 0,0176, branching 0,0016)

- A first method to determine the ^{226}Ra activity concentration is taken care that the daughters, e.g. ^{214}Pb and ^{214}Bi, are in equilibrium with ^{226}Ra. The maximum ingrowth time can cover 21 days (T1/2 of ^{222}Rn is 3,8235 days). The throughput time from sending the sample to the lab up to receiving the analysis report may take 24 days

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Part 2: I-Want-It-Now, ^{226}Ra activity concentration

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- A second method (screening method) is based on the above method and has an ingrowth time of 5 days.

- Determination of the ^{226}Ra activity concentration without the need that "daughters" have to be in equilibrium will be an huge advantage for the non-nuclear industry and such a method anticipates on I-WIN

- It can be concluded that a method, that anticipates on I-WIN, needs to be able to determine the activity concentration from ^{238}U and/or ^{235}U in order to estimate the activity of ^{226}Ra.

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Part 2: I-Want-It-Now, ^{226}Ra activity concentration

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- Overview of the major gamma lines involved for ^{238}U and ^{235}U:

^{238}U			^{235}U	
Nuclide	E[keV]	fa[ ]	E[keV]	fa[ ]
^{234}Th	63.3	0,0375	143.77	0.1094 (interference by ^{230}Th and ^{223}Ra)
^{234m}Pa	1001.03	0.00847	163.36	0.0508 (interference by ^{231}Th)
			185.72	0.572 (interference by ^{226}Ra)

- These interferences should be taken care of as good as possible and a weighted activity concentration of ^{238}U or ^{235}U can be calculated.
- However, take in mind , that when applying a conservative approach and the activity concentration is (statistical significant) below the exemption level or building index <1. No future actions are needed.

Finalized: Part 2: I-Want-It-Now; ^{226}Ra activity concentration

Questions ?

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Part 3: Intercomparison of instruments and methods for NORM generated by the Non-Nuclear Industry

Contents

- Introduction
- Aim of this intercomparison
- Criteria
- Intercomparison of instruments and methods
- Conclusion

Introduction

- Awareness of regulators

  Nuclear → Euratom
- Remains and waste from the non-nuclear industrial processes
- European Directives 1996/29 and 2013/59/Euratom
- National regulations
- Impact on actions and measures

AIM

To provide an overview by means of an intercomparison a global overview of the applicability of instruments and methods for the characterization of NORM in the non-nuclear industry, to assess in daily routine:

- Elevated radiological health risks and to assist in the decision making process to take adequate measures;
- The level of the radiological contamination of materials;
- The instruments and methods that can be applied to prove to be in compliance with National regulations.

Criteria	**Abbreviation**
Operational	
• Hand-Held / Laboratory	H-H / Lab
• Operator / Specialist	Opr / Spc
• Time passed before results are available	Avail of results
• Assisting Health physicist by taken direct actions / measures	Health phys
• Costs	Costs

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Criteria (continued)	**Abbreviation**
Regulatory	
• Regulations	Regulations
NORM specific	
• Equilibrium detection/correction (e.g. parent and daughter are not in equilibrium)	Equil corr
• Nuclide identification / indication	Nucl ident/indic
• Nuclide interference correction	Nucl interf

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Criteria (continued)	**Abbreviation**
Technical	
• Non-destructive analysis / Destructive analysis	NDA / DA
• Detector calibration	Detec calib
• Sample geometry correction (sample holder is not equal to a calibrated geometry)	Sample calib corr
• Self-absorption correction: density	S-abs rho
• Self-absorption correction: chemical composition	S-abs chm comp

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Criteria (continued)	**Abbreviation**
Technical	
• Non-destructive analysis / Destructive analysis	NDA / DA
• Detector calibration	Detec calib
• Sample geometry correction (sample holder is not equal to a calibrated geometry)	Sample calib corr
• Self-absorption correction: density	S-abs rho
• Self-absorption correction: chemical composition	S-abs chm comp

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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Criterion	Score				
	++	+	+/-	-	--
Operational					
H-H / Lab	Hand-Held	-	-	-	Laboratory
Operator / Specialist	Operator				Specialist
Avail. of results	Direct				> 21 days
Health physics	No other instrument of method needed				No added value
Costs	Cheap				Very expensive
Regulatory					
Regulations	No other instrument of method needed	-	-	-	No added value
NORM specific					
Equil corr	Accurate	-	-	-	Not possible
Nucl ident/indic	Accurate Identification				Not possible
Nucl interference	Accurate				Not possible
Technical					
NDA / DA	Non-Destructive Analysis	-	-	-	Destructive Analysis
Detec calib	Accurate				Not possible
Smpl calib corr	Accurate				Not possible
S-abs rho	Accurate				Not possible
S-abs chm comp	Accurate				Not possible

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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Instruments and analyze methods	Abbreviation
Laboratory	
α-spectroscopy	α-spec
β-spectroscopy	β-spec
Gross α/β counting	Gross α/β
Hand-held monitors	
α/β contamination	Gross α/β cont
Dose rate	Dose rate
γ-spectroscopy low-resolution (e.g. NaI(Tl), CsI)	γ-spec LR
γ-spectroscopy intermediate-resolution (e.g. $LaBr_3$, $CeBr_3$, SrI_2)	γ-spec IntR
Dose rate & γ-spectroscopy intermediate-resolution	Dose R & γ-spec IntR

Instruments and analyze methods	Abbreviation
γ-spectroscopy	
• **Hand-held monitors**	
• γ-spectroscopy low-resolution (e.g. NaI(Tl), CsI)	H-H, γ-spec LR
• γ-spectroscopy intermediate-resolution (e.g. $LaBr_3$, $CeBr_3$ low background, SrI_2, CdZn(Te))	H-H, γ-spec IntR
• **Laboratory systems**	
• γ-spectroscopy Intermediate-Resolution	Lab, γ-spec IntR
• γ-spectroscopy high-resolution (e.g. HPGe N-type low Bg) including a density correction	Lab, γ-spect HR ρ
• γ-spect high-resolution incl. a transmission technique	Lab, γ-spect HR Tr
• γ-spect high-resolution incl. a μ-over-ρ technique	Lab, γ-spect μ-over-ρ

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Part 3: Intercomparison of instruments and methods for NORM

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Assessment: α-spectroscopy

- Destructive; unlocking the sample
- Electrodeposition
- Sample geometry; thickness of a few atoms
- Vacuum (preferable < 1.10^{-3} mBar)
- Nuclide identification by analysis software or manual
- Specialist

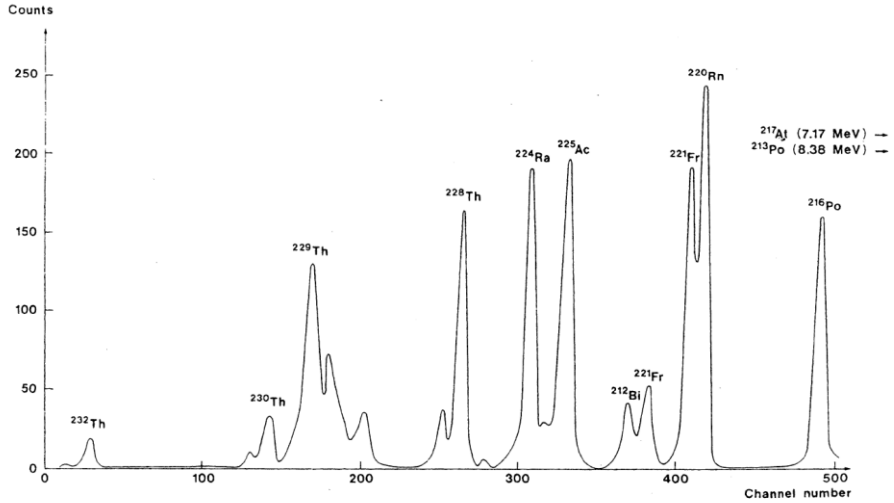

Fig. 3. Alpha spectrum after thorium separation from sea water and electrodeposition using ^{229}Th as yield determinant, with a surface barrier Si-detector (From Holm, 1984).

Criterion	α-spec
Operational	
H-H / Lab	Lab
Opr / Spc	Spc
Avail of results	--
Health phys	--
Costs	--
Regulatory	
Regulations	-
NORM specific	
Equil corr	--
Nucl ident/indic	+
Nucl interf	+
Technical	
NDA / DA	DA
Detec calib	+
Smpl calib corr	n.a.
S-abs rho	n.a.
S-abs chm comp	n.a.

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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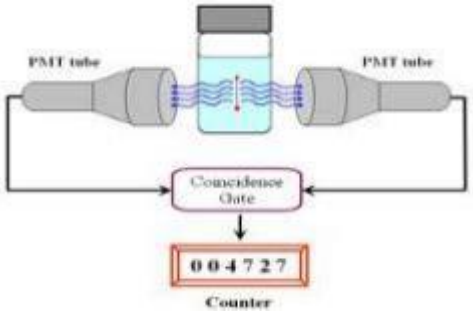
Assessment: β-spectroscopy

- Destructive; sample preparation
- Adding to the scintillator
- Sample geometry; depending on vial, quenching, etc.
- Scintillator is sensitive for visible light
- Nuclide identification by analysis software or manual
- Specialist

Criterion	β-spec
Operational	
H-H / Lab	Lab
Opr / Spc	Spc
Avail of results	--
Health phys	--
Costs	--
Regulatory	
Regulations	-
NORM specific	
Equil corr	--
Nucl ident/indic	+/-
Nucl interf	+/-
Technical	
NDA / DA	DA
Detec calib	+
Smpl calib corr	n.a.
S-abs rho	n.a.
S-abs chm comp	n.a.



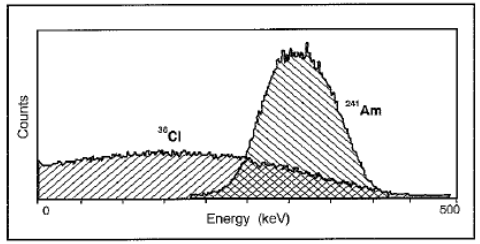


Figure 3-2.
Multichannel analyzer display, alpha/beta interferences.

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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Assessment: Gross α/β-counting

- Destructive; sample preparation (not for swipe tests)
- No correction for density and chemical composition
- Sample geometry equal to detector size
- Nuclide identification not possible
- Specialist or well trained operator

Criterion	Gross α/β
Operational	
H-H / Lab	Lab
Opr / Spc	Spc/Opr
Avail of results	-
Health phys	+/-
Costs	+/-
Regulatory	
Regulations	-
NORM specific	
Equil corr	--
Nucl ident/indic	--
Nucl interf	+/-
Technical	
NDA / DA	DA
Detec calib	+
Smpl calib corr	n.a.
S-abs rho	n.a.
S-abs chm comp	-

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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Assessment: Hand-Held α/β-contamination

- Non-destructive; no sample preparation
- No correction for density and chemical composition
- Sample (measuring) geometry in principal equal to detector size
- Equipment is vulnerable, especially the foil
- Nuclide identification not possible
- Operator

Criterion	Gross α/β cont
Operational	
H-H / Lab	H-H
Opr / Spc	Opr
Avail of results	++
Health phys	++
Costs	+
Regulatory	
Regulations	+/-
NORM specific	
Equil corr	--
Nucl ident/indic	--
Nucl interf	--
Technical	
NDA / DA	NDA
Detec calib	+/-
Smpl calib corr	--
S-abs rho	--
S-abs chm comp	--

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

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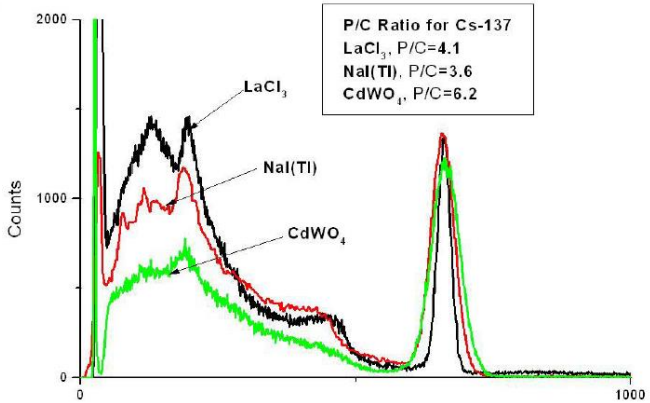
Assessment: Hand-Held Dose Rate – γ spec int. resolution

- Non-destructive; no sample preparation
- No correction for density, chemical composition and detector properties
- The "Dose rate" sample (measuring) geometry is in general not defined and thus the γ-detector might not be calibrated
- Nuclide identification/indication is possible
- Operator



M.Swoboda e.a.; Spectral gamma detector RID; 2004 IEEE

Criterion	Dose R & γ-spec IntR
Operational	
H-H / Lab	H-H
Opr / Spc	Opr
Avail of results	++ & +
Health phys	++ & +
Costs	+/-
Regulatory	
Regulations	+/-
NORM specific	
Equil corr	--
Nucl ident/indic	+
Nucl interf	--
Technical	
NDA / DA	NDA
Detec calib	+/-
Smpl calib corr	+/-
S-abs rho	--
S-abs chm comp	--

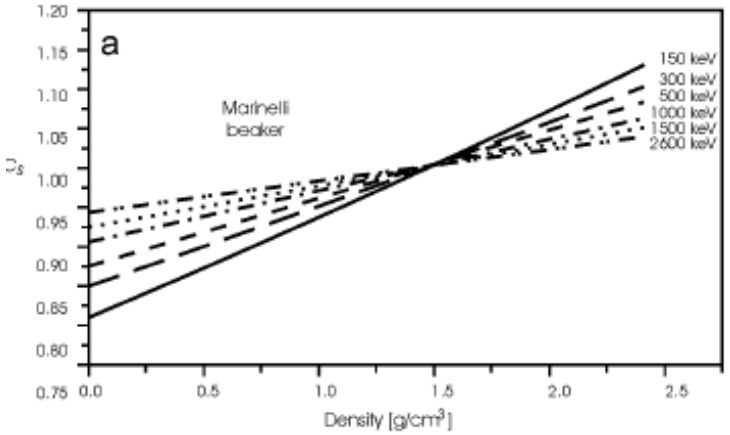
NORM characterization and applied metrology

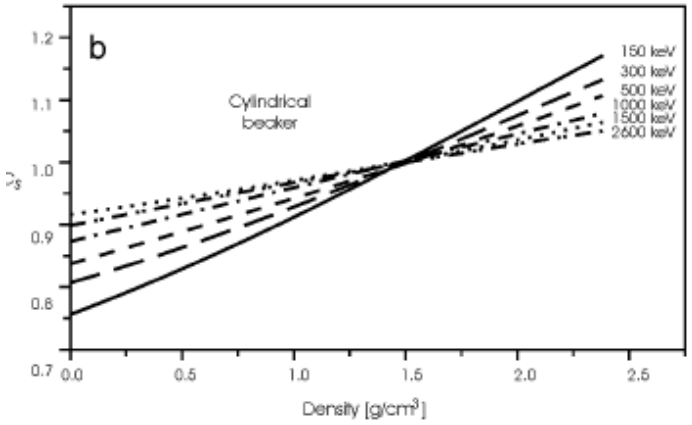
Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Assessment: Lab γ spectroscopy high resolution–density correction

- Non-destructive; sample preparation for sample holder
- Self absorption correction only based on density of the sample
- No correction for chemical composition and detector properties
- Sample geometry is defined, equal to a calibration geometry
- Nuclide identification
- Specialist





Criterion	γ-spec HR φ
Operational	
H-H / Lab	Lab
Opr / Spc	Spc
Avail of results	-
Health phys	-
Costs	--
Regulatory	
Regulations	+
NORM specific	
Equil corr	+/-
Nucl ident/indic	+
Nucl interf	+
Technical	
NDA / DA	NDA
Detec calib	+
Smpl calib corr	+
S-abs rho	+
S-abs chm comp	-

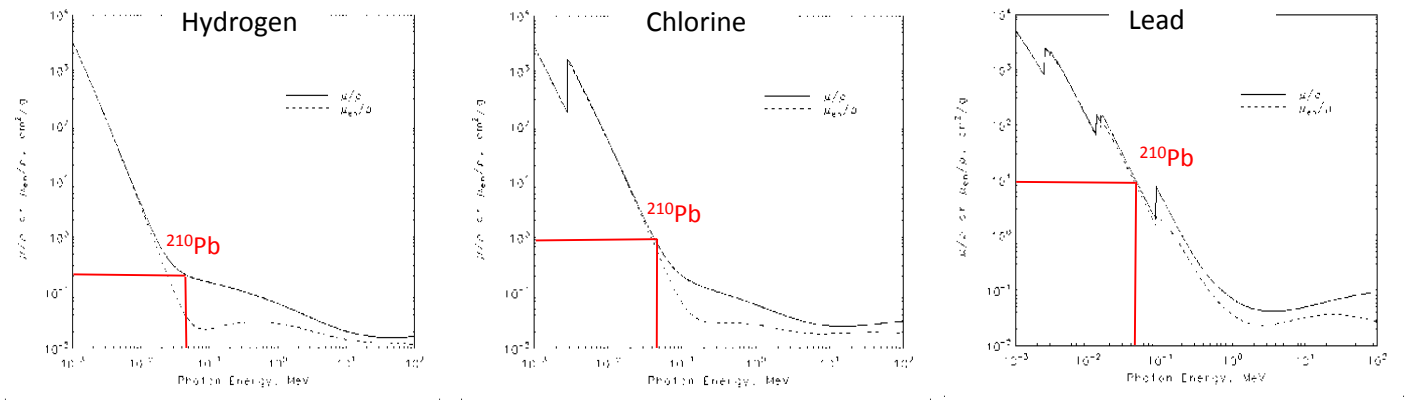
NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Assessment: Lab γ spectroscopy high resolution – transmission correction

- Non-destructive; sample preparation for sample holder
- Self absorption correction: density and limited for chemical composition
- No correction detector properties
- Sample geometry is defined, equal to a calibration geometry
- Nuclide identification
- Specialist



Criterion	γ-spec HR Tr
Operational	
H-H / Lab	Lab
Opr / Spc	Spc
Avail of results	-
Health phys	-
Costs	--
Regulatory	
Regulations	+
NORM specific	
Equil corr	+
Nucl ident/indic	+
Nucl interf	+
Technical	
NDA / DA	NDA
Detec calib	+
Smpl calib corr	+
S-abs rho	+
S-abs chm comp	+

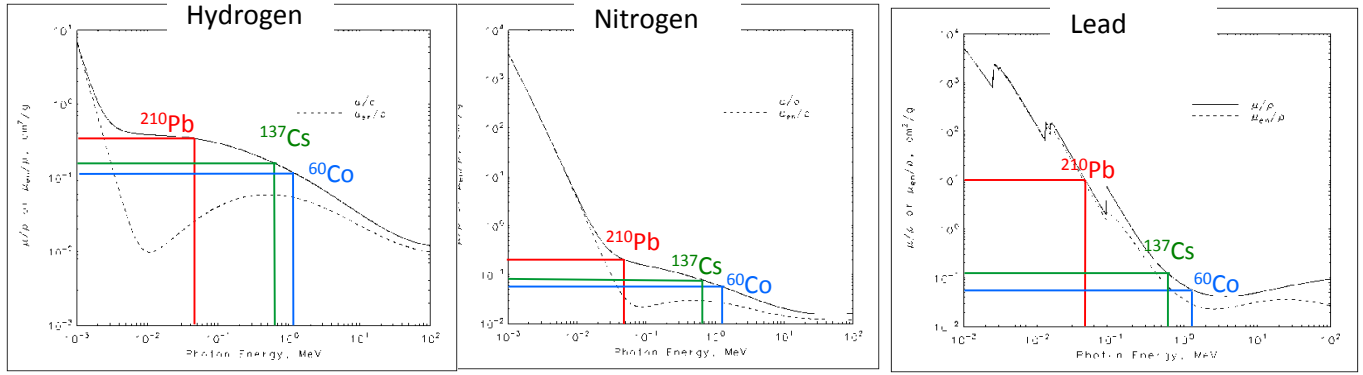
NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Assessment: Lab γ spectroscopy high resolution – "μ-over-ρ" correction

- Non-destructive; sample preparation for sample holder
- Self absorption correction: density and chemical composition
- Correction for detector properties
- Sample geometry is defined, equal to a calibration geometry or by simulation
- Nuclide identification
- Specialist



Criterion	γ-spec HR μ-over-φ
Operational	
H-H / Lab	Lab
Opr / Spc	Spc
Avail of results	-
Health phys	-
Costs	--
Regulatory	
Regulations	+
NORM specific	
Equil corr	++
Nucl ident/indic	++
Nucl interf	+
Technical	
NDA / DA	NDA
Detec calib	++
Smpl calib corr	+
S-abs rho	++
S-abs chm comp	++

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Overview: Lab systems & methods

Criterion	α-spec	β-spec	Gross α/β
Operational			
H-H / Lab	Lab	Lab	Lab
Opr / Spc	Spc	Spc	Spc/Opr
Avail of results	--	--	-
Health phys	--	--	+/-
Costs	--	--	+/-
Regulatory			
Regulations	-	-	-
NORM specific			
Equil corr	--	--	--
Nucl ident/indic	+	+/-	--
Nucl interf	+	+/-	+/-
Technical			
NDA / DA	DA	DA	DA
Detec calib	+	+	+
Smpl calib corr	n.a.	n.a.	n.a.
S-abs rho	n.a.	n.a.	n.a.
S-abs chm comp	n.a.	n.a.	n.a.

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Overview: Hand-Held systems & methods

Criterion	Gross α/β cont	Dose rate	γ-spec LR	γ-spec IntR	Dose R & γ-spec IntR
Operational					
H-H / Lab	H-H	H-H	H-H	H-H	H-H
Opr / Spc	Opr	Opr	Opr	Opr	Opr
Avail of results	++	++	+	+	++ & +
Health phys	++	++	+	+	++ & +
Costs	+	+	+/-	+/-	+/-
Regulatory					
Regulations	+/-	+/-	-	-	+/-
NORM specific					
Equil corr	--	--	--	--	--
Nucl ident/indic	--	--	+/-	+	+
Nucl interf	--	--	--	--	--
Technical					
NDA / DA	NDA	NDA	NDA	NDA	NDA
Detec calib	+/-	+	+/-	+/-	+/-
Smpl calib corr	--	--	+/-	+/-	+/-
S-abs rho	--	--	--	--	--
S-abs chm comp	--	--	--	--	--

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Overview:

γ spectroscopy systems & methods

Criterion	γ-spec LR	γ-spec IntR	Dose R & γ-spec IntR	γ-spec IntR	γ-spec HR φ	γ-spec HR Tr	γ-spec HR μ-over-φ
Operational							
H-H / Lab	H-H	H-H	H-H	Lab	Lab	Lab	Lab
Opr / Spc	Opr	Opr	Opr	Opr	Spc	Spc	Spc
Avail of results	+	+	++ & +	+	-	-	-
Health phys	+	+	++ & +	+	-	-	-
Costs	+/-	+/-	+/-	-	--	--	--
Regulatory							
Regulations	-	-	+/-	+	+	+	+
NORM specific							
Equil corr	--	--	--	+/-	+/-	+	++
Nucl ident/indic	+/-	+	+	+	+	+	++
Nucl interf	--	--	--	+	+	+	+
Technical							
NDA / DA	NDA	NDA	NDA	NDA	NDA	NDA	NDA
Detec calib	+/-	+/-	+/-	+	+	+	++
Smpl calib corr	+/-	+/-	+/-	+	+	+	+
S-abs rho	--	--	--	+/-	+	+	++
S-abs chm comp	--	--	--	+/-	-	+	++

NORM characterization and applied metrology

Part 3: Intercomparison of instruments and methods for NORM

EURSSEM Environmental

Overview:

γ spectroscopy systems & methods

Criterion	γ-spec LR	γ-spec IntR	Dose R & γ-spec IntR	γ-spec IntR	γ-spec HR φ	γ-spec HR Tr	γ-spec HR μ-over-φ
Operational							
H-H / Lab	H-H	H-H	H-H	Lab	Lab	Lab	Lab
Opr / Spc	Opr	Opr	Opr	Opr	Spc	Spc	Spc
Avail of results	+	+	++ & +	+	-	-	-
Health phys	+	+	++ & +	+	-	-	-
Costs	+/-	+/-	+/-	-	--	--	--
Regulatory							
Regulations	-	-	+/-	+	+	+	+
NORM specific							
Equil corr	--	--	--	+/-	+/-	+	++
Nucl ident/indic	+/-	+	+	+	+	+	++
Nucl interf	--	--	--	+	+	+	+
Technical							
NDA / DA	NDA	NDA	NDA	NDA	NDA	NDA	NDA
Detec calib	+/-	+/-	+/-	+	+	+	++
Smpl calib corr	+/-	+/-	+/-	+	+	+	+
S-abs rho	--	--	--	+/-	+	+	++
S-abs chm comp	--	--	--	+/-	-	+	++

Conclusion and discussion

- No single instrument & method covers adequate all health protection and regulatory compliances.
- Dealing with the best practices with NORM in the non-nuclear industry a combination of:
  - Hand held α/β contamination monitor
  - Hand held dose rate monitor or a hand-held dose rate including an isotope identifier
  - Lab gamma-spectroscopy intermediate resolution

  may be applied to cover all radiological aspects for health physics and regulatory control compliances in the non-nuclear industry, e.g. assessing the radiological contamination -, the total activity – and the nuclide specific activity concentration of NORM.

Conclusion and discussion (continued)

- Future developments: it can be expected that the specifications and options of :
  - “Hand held dose rate monitor including an isotope identifier” will evaluate towards a “hand held dose rate monitor including an intermediate-resolution gamma-spectroscopy system” suited to prove that regulations compliances are fulfilled.
  - A “gamma-spectroscopy intermediate-resolution system” will evaluate towards a “gamma-spectroscopy high resolution system” for routine/daily purposes.

Finalized: Part 3: Intercomparison of instruments and methods for NORM

Questions ?

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EURSSEM Environmental

Thank you for your attention and participation in IRPA2018 Refresher Course

"NORM Characterization and applied Metrology"

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