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Characterisation of rooms and buildings concrete surfaces for decontamination and free-release at NPP A-1, Slovakia

Alojz Slaninka, Ondrej Slávik

VUJE, Inc., Okružná 5, 918 64 Trnava, Slovak republic,
slaninka@vuje.sk +421 (33) 599 1462, slavik@vuje.sk +421 (33) 599 1461

ABSTRACT:

Dominant contamination at NPP A-1 is caused by long-living ^{137}Cs that may occur in concrete structures. Therefore, characterisation is required for determination the method and range of decontamination (before decontamination) as well as for scope and range of free release measurement (after decontamination).

The base of characterisation is monitoring of total activity in the structure per unit surface area [Bq/cm^2]. This approach is in compliance with international recommendation RP-113. Measuring equipment including hand-held gamma spectrometry assembly with scintillation LaBr 1.5” x 1.5” detector was applied. The measuring assembly was certified by Slovak Metrology Institute as measuring instrument of 15% accuracy class.

The proposed method, estimation of measurement uncertainty and other support characterisation methods as well as results and experience from a pilot in situ monitoring of a large concrete tank are discussed in more detail in this paper.

Keywords: contamination depth, density of monitoring network, in situ monitoring, total activity in the structure per unit surface area

Monitoring of total activity in the structure per unit surface area (TAUSA)

Description of measuring instrument assembly

- Hand-held gamma spectrometer InSpector 1000 (1024 channels, internal power supply, flash memory for spectra saving),
- Scintillation LaBr 1.5“ x 1.5“ detector type IPROL-1 (energy resolution about 4 % at 661.6 keV, temperature stabilisation of energy spectra)

Basic metrological specifications

- Counting geometry: detector in contact to monitored concrete surface
- Monitoring in regular square grid with 1 m step
- Effectively monitored area: 1 m^2 (about 80% total response, **Fig.1, Tab. 1**)
- Measurement sensitivity of TAUSA ^{137}Cs: 3.13 s^{-1}/(Bq/cm^2) at concrete density 2.35 g/cm^3 and1 cm effective depth of contamination (1 cm depth is adequate for most cases)
- MDA on the level 0.5 Bq/cm^2 for ^{137}Cs at the 0.1 µSv/h gamma radiation background and 100 s acquisition time
- Productivity of measurement: about 40 m^2 per working shift by two workers
- Detection efficiency determination: by ISOCS mathematical calibration tool

Estimation of average measurement uncertainty

- It was evaluated on the basis the variation of most significant parameters affecting the measurement result (input data to detection efficiency calculation), estimated for 661.6 keV (^{137}Cs) **Tab. 2**
- Uncertainty in consequence inhomogeneous activity distribution on monitored surface was evaluated by „hot spot“ occurrence modelling, **Tab. 3, Fig. 5**

Tab. 1 Dependence of the detected response distribution on contamination depth, at detector placement in the centre of circular concrete surface area

Contamination depth [cm]	Contribution of the response from the circular area with given diameter		
	100 cm	200 cm	400 cm
0.5	72 %	85 %	92 %
1.0	79 %	89 %	95 %
2.0	85 %	92 %	96 %

Fig. 1 Distribution of the detected response on the monitored concrete surface with marked monitoring 1 m regular grid at contamination depth 1 cm

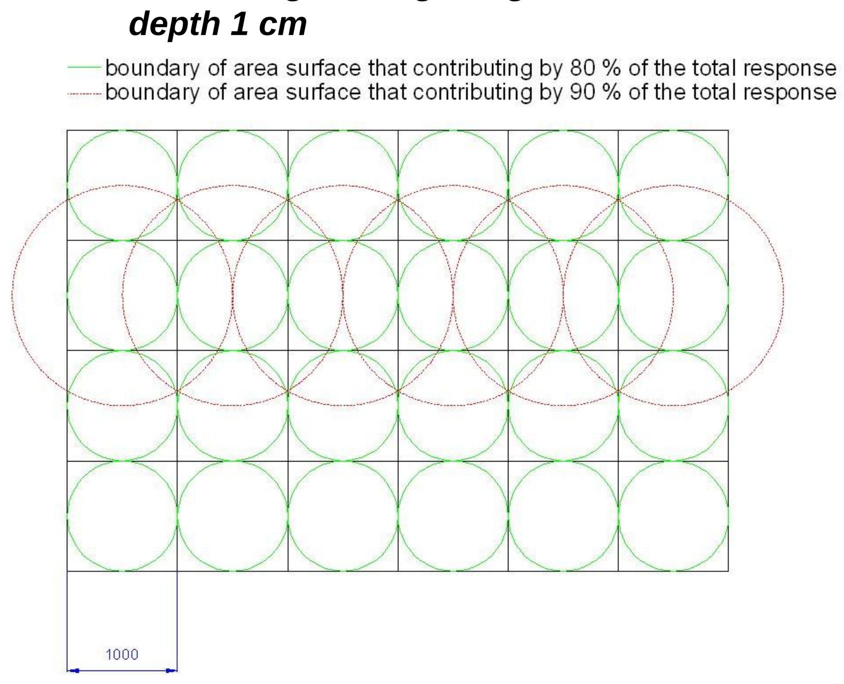


Fig. 2 Distribution of measurement sensitivity on monitored area, measurement sensitivity to area of particular annulus is shown at various contamination depths

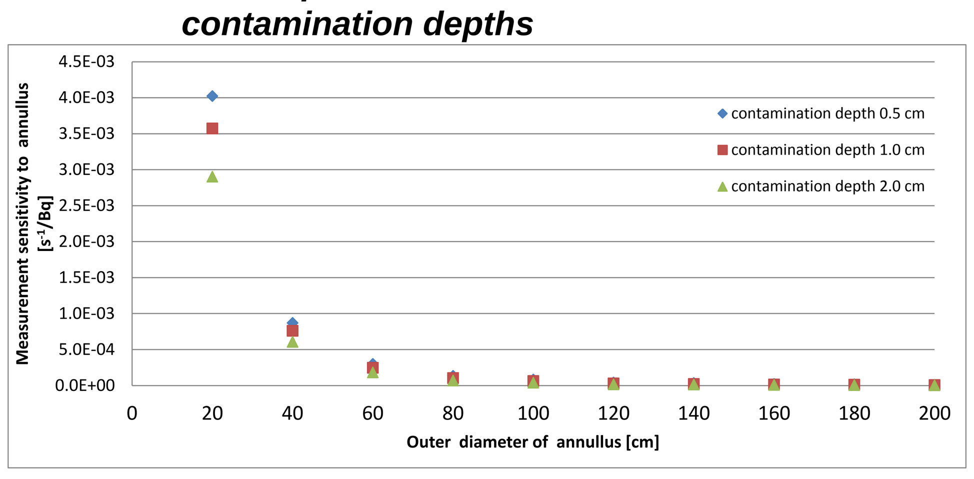


Fig. 3 Dependence of TAUSA measuring sensitivity on the concrete density of monitored surface, for circle area of 4 m diameter and 1 cm contamination depth

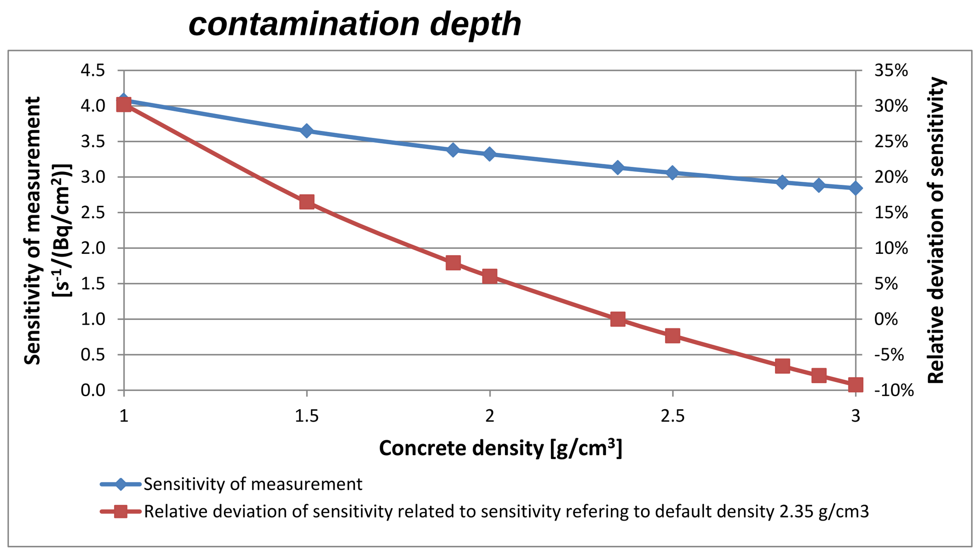
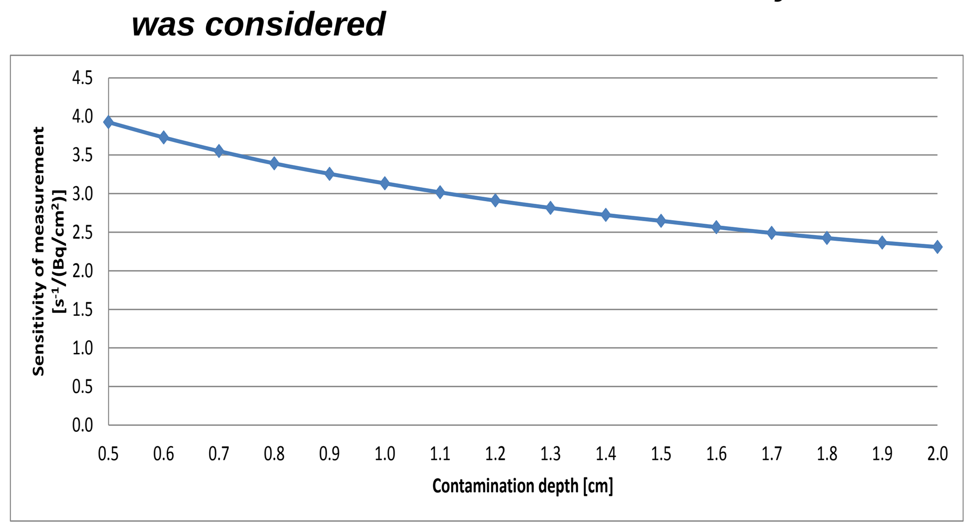


Fig. 4 Dependence TAUSA measurement sensitivity on the contamination depth, even activity distribution in contaminated concrete layer was considered



Others characterisation measurements

Preliminary dose rate survey

- Identification and removing of a “hot spots” (> 10 µSv/h) - decrease of an external interfering radiation and workers dose burden.
- Identification the boundaries of areas of increased contamination (> 2 µSv/h).

Determination of effective contamination depth

- It is required for choose of adequate decontamination method.
- Taken concrete samples are used also:
  - to radiochemistry determination of specific activity of the hard to detectable radionuclides - HDRN (e.g. ^{90}Sr, ^{241}Am or isotopes of Pu that are alpha or beta emitters only),
  - to eliminate contamination of the concrete structure in depth.

Destructive methods – sampling by core and common drill

Sampling by core drill

- Segmentation of core drills by means of a circular saw to particular segments.
- Analyzing of particular segments by laboratory semiconductor gamma spectrometry.
- Checking of the homogenous activity distribution in the particular segments by compare response from the both segment sides.
- Inhomogeneous segments (the difference of the responses exceeds 20 %) are powderized by the hydraulic press equipment and homogenised before analysing.

Sampling by common drill

- The set of common drills with various diameters is used.
- Firstly the drill with maximum diameter is used.
- Next bore on the same site is carry out by drill with smaller diameter in comparison with the previous one.

Non destructive in situ method

- The *in situ* semiconductor gamma spectrometry with shielded HPGe detector.
- Effective contamination depth is determined by the ratio of net full energy peak area of 661.6 keV (^{137}Cs) gamma ray and net full energy peak area of 32 keV X-ray (^{137}Cs).

Monitoring of surface contamination

- Monitoring by hand-held measuring instruments based on the sum beta radiation detection (gas proportional or plastic scintillation detectors with sensitive area less 200 cm^2).
- Measurement of thin surface layer (about 1 mm) only due to the beta radiation detection.
- Surface contamintion monitoring is used to:
  - more precious “hot spot” identification and to demarcation of the areas of increased contamination,
  - evaluation of the homogeneity of activity distribution on the monitored area.
- Ratio of measured surface activity (based on the beta ray detection) and total activity in the structure per unit surface area (based on the gamma ray detection) may be an indicator of the contamination depth.

Tab. 2 Estimation of average uncertainty of TAUSA measurement and its most important components

Source of uncertainty	Uncertainty
Uncertainty of calibration method ISOCS (for 661.6 keV energy)	6%
Uncertainty resulting from change the density of concrete structure (2.35 ± 0.5) g/cm^3	8%
Uncertainty resulting from change the contamination depth (1 ± 0.3) cm	13.3%
Uncertainty resulting from change the detector position during counting (in contact ± 2 cm)	3.7%
Uncertainty of net peak area determination (100 s, As = 8 Bq/cm^2)	3%
Standard combined uncertainty (at homogeneous activity distribution)	**17%**
Uncertainty resulting from inhomogeneous activity distribution on the monitored surface	9%
Standard combined uncertainty (including inhomogeneous activity distribution)	**20%**

Tab. 3 Deviations of measured activity value (supposing even activity distribution) from real activity value on the monitored surface area at “hot spot” occurrence according to Figure 5

Scenario	a)	b)	c)	d)	e)	Average
Deviation	2 %	0	8 %	16 %	19 %	9 %

Fig. 6 Example of decontaminated and non-decontaminated internal concrete surface of tank with demarcated monitoring grid

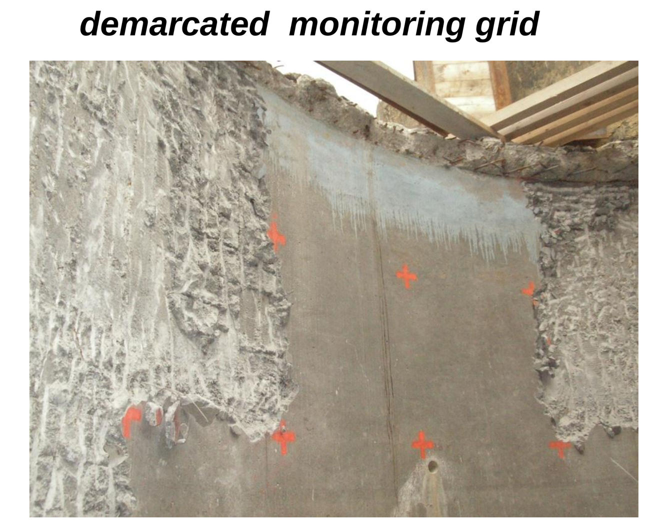
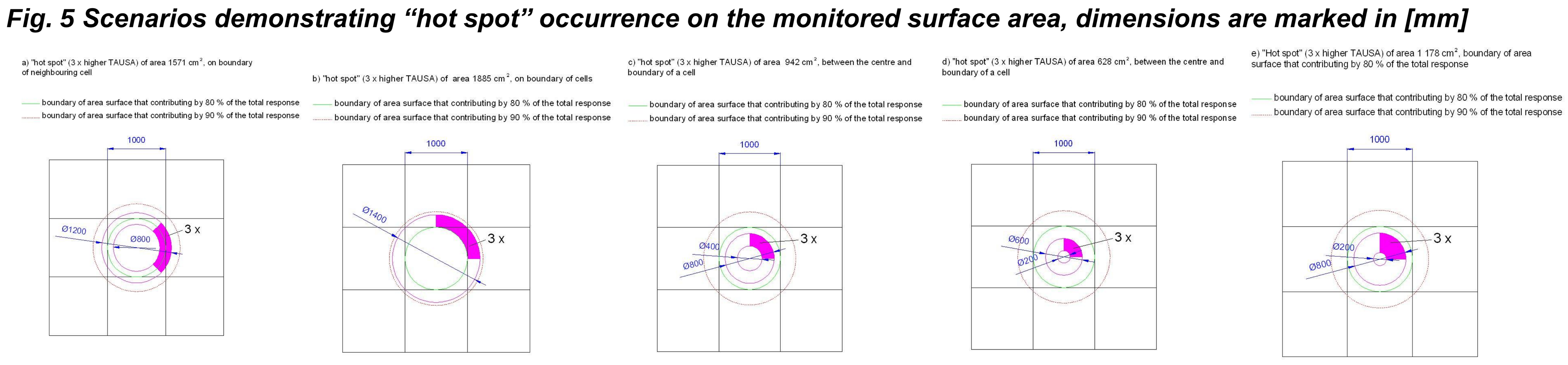


Fig. 5 Scenarios demonstrating “hot spot” occurrence on the monitored surface area, dimensions are marked in [mm]



Conclusions:

An innovative method of measurement of the total activity in the structure per unit surface area [Bq/cm^2] that is based on hand-held gamma spectrometer Inspector1000 with LaBr 1.5” x 1.5” scintillation detector was designed and tested. This method is in compliance with international recommendation RP-113. To evaluate the TAUSA measurements the knowledge of effective contamination depth is necessary but for most of cases 1 cm can be supposed.

The monitoring method as well as the other support characterisation methods including dose rate survey, contamination depth determination etc. are described in the paper. Analyse of TAUSA measurement uncertainty was carry out too. Estimated standard combined uncertainty was on the level 17 % at even and 20 % at uneven radioactivity distribution on the monitored area.

The measuring assembly was metrologically tested for such measurements by Slovak metrology institute (SMÚ) in Bratislava and was classified as activity measuring instrument of radionuclides emitting gamma ray of 15% accuracy class.

Introduced approach was tested within decommissioning project of NPP A1 in Slovakia at characterisation of surfaces of the tanks concrete used as liquid radioactive waste storage. Preliminary clearance limit for TAUSA was choices on the level 8 Bq/cm^2. Average measured value was 8.3 Bq/cm^2. After removing the surface contaminated layer of thickness 1 – 5 cm the average TAUSA value decreased to 3.7 Bq/cm^2.

Fig. 7 Map of the tank concrete internal surface contamination expressed by the total activity in the structure per unit surface area (TAUSA) of ^{137}Cs [Bq/cm^2] measured in the regular grind 1 x 1 m