Centre for Energy Research

Source-Activity Measurement with Scintillation Crystal Based Detectors under Field Conditions

IAEA (nuclear security department) CRP: Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control

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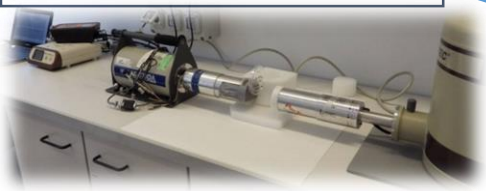
The spectrum in activity, facility and capability of NSD is on wide range

Nuclear Security Department (NSD)

Radioactive waste characterization

Gamma Lab
Non - destructive analysis



ICP-MS Lab
Destructive analysis

Neutron Lab
Development of instruments (PTR)

Virtual Gamma Lab
Virtual Training facility

Real Training facility

Detector Testing Lab

Temporary storage for confiscated materials

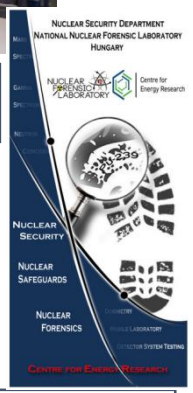
Nuclear Industry (Verification of enrichment in fuel assemblies)

Dosimetry and alfa spect. Lab

Education, training

Nuclear Forensics

NUCLEAR FORENSIC LABORATORY



Mobile Lab
Mobile Expert Support Team
In-field Detection

Radioactive source exploration from the aspect of NSD

All elements of the chain are implemented by NSD

Common procedure → Trainings at training sites → Real case Source detection, localization → Source investigation (1), measurements:
- Nuclide identification
- Dose rate measurement

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Source investigation (2), calculations:
- Source-Activity
- Physical protection category

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Transportation to the storage facility

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Further source investigation (3):
- Forensic laboratory

Trainings at training sites → Virtual Radioactive Source System

Trainings at training sites → Real sources, real measurement devices

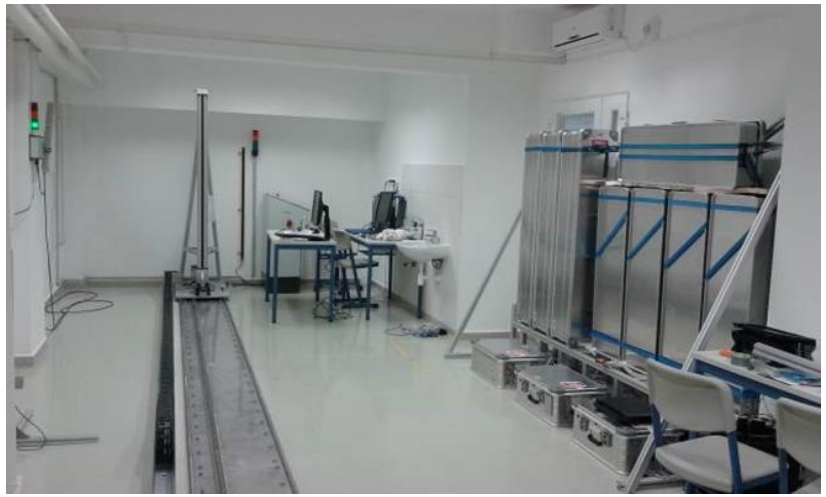
CRP on SOURCE-ACTIVITY MEASUREMENT WITH SCINTILLATION CRYSTAL BASED DETECTORS UNDER FIELD CONDITIONS

Introduction of Detector Testing Laboratory of the NSD (CER)

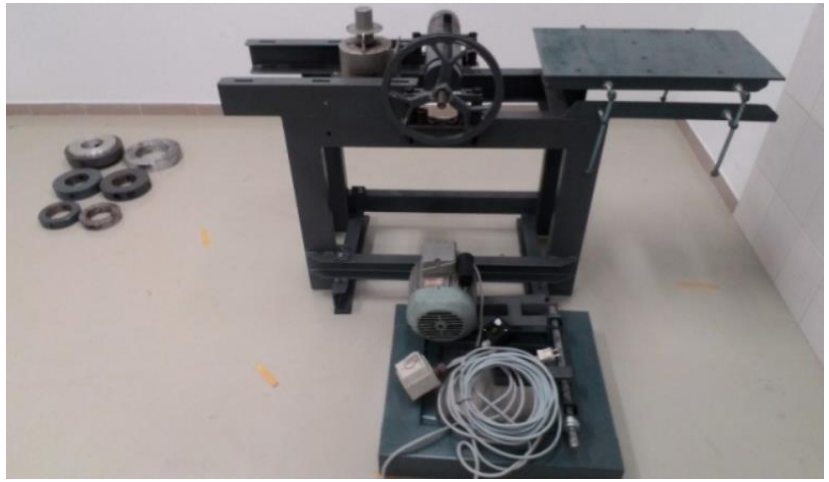
Established in 2015 to ensure the necessary technical background for the development of nuclear instruments and detection systems for Nuclear Security purposes.

- Dynamic tests with 11 m track length and scalable source height up to 2,5 m
- Static tests with scalable-speed source carrying torpedo,
- Remote control and pre-programmable test parameters
- Controlled environmental conditions
- Pulsed fields investigations

Panorama irradiators gamma, neutron



Line track



Gamma-chopper

Overview of this new application as optional functionality

Developed and tested an activity-estimation method for unknown radioactive sources under field conditions as a new RIID application

Importance in:

- Evaluation of declared commodity information or found illegal cargo
- Physical protection
- Laboratory
- Transportation

Theoretical and practical results in:

- Creating and developing a method
- Implementation
- Uncertainties
- Performance

Difficulties contrast to laboratory conditions e.g.:

- source found in a closed barrel or container and not allowed to get open
- not well-known quality and thickness of the shielding material
- not well-known quality and thickness of the filling material
- can’t use the source-detector distance of 30 cm
- insufficient information about source distribution
- unknown source dimensions
- insufficient information about source - barrel wall distance
- not so much time is available to measure

Overview of the CRP

LaBr scintillation crystal based detector capabilities

1st phase of the project

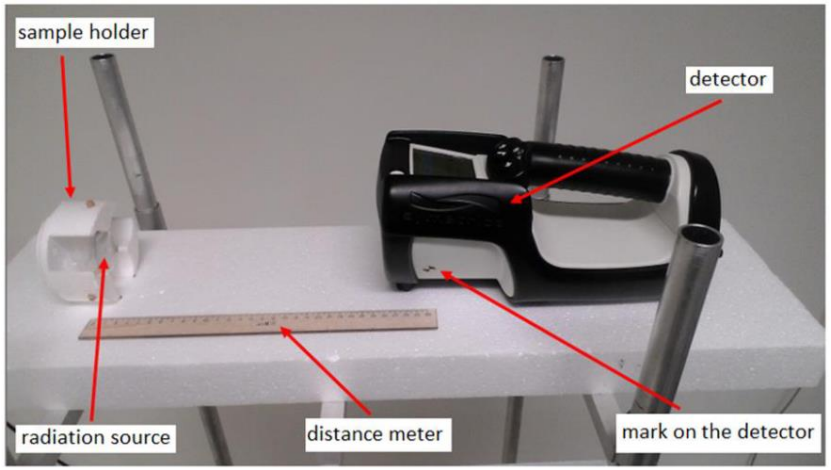
Radiation quality info:
Source-Identification

Source-Identification probability

According to RIID standards
IEC 62327
ANSI N42.34

2nd phase

Radiation quantity info:
Source-Activity

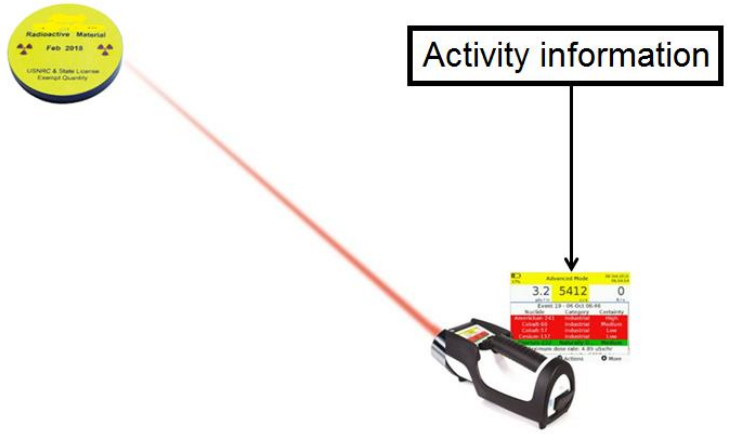


Source-Activity information at 30 cm distance

According to standard
IEC 61453:2007
~~IEC 61452:2021~~

Final goal of the CRP

Extension of 2nd phase with additional variables



Source-Activity information at any distance and with any shielding
Non-standardised, novel, automated application

Research Methodology

Problem approach - Researcher attitude

Measurement procedure/method development

According to ISO 17025 standard

For reliable results

Source-Activity?
The result: about 12.489 GBq

Uncertainty is properly estimated and evaluated

This whole project is a recommendation, illustrating the problems that can arise with examples: How to get started on the road if you want to comply with the ISO 17025 standard.

Source-Activity?
The result: 12.5 ± 3.1 GBq
k=2

Focus:

- An example: radiation barrel is found on the field
- Assess and reduce unknown data
- Assess and reduce uncertainties

Theoretical formulas are verified with alternative, independent measurement method

Standardised formula:

$$A_i = \frac{\dot{N}_{i,30\ cm}}{P_{\gamma i} * Eff_{Ei}}$$

Source-Activity information at any distance and any shielding

$$A_i = C_x * C_{shield} * \frac{\dot{N}_{i,x_{Eff}}}{P_{\gamma i} * Eff_{Ei}}$$

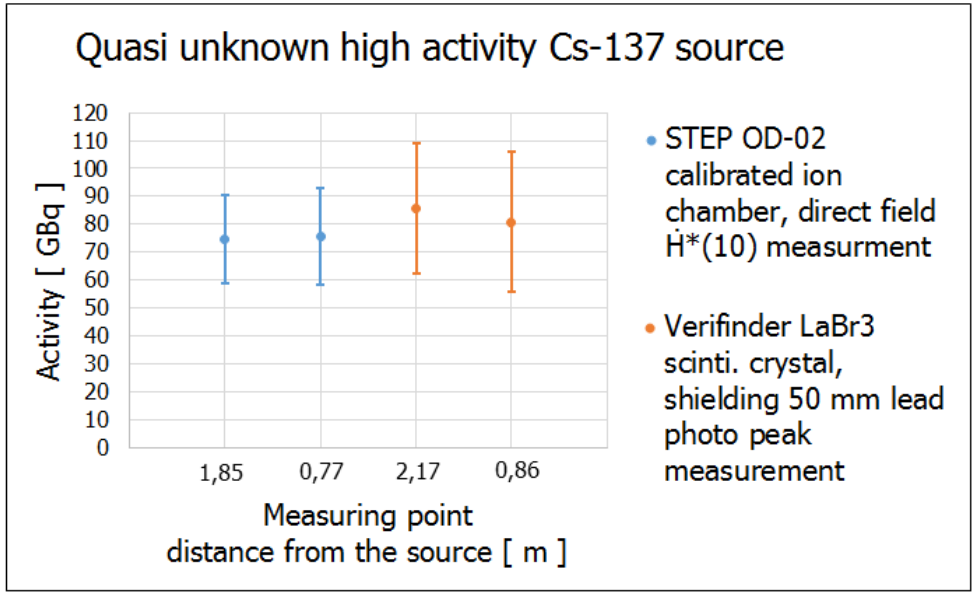
Extended (Non-standardised) formula

According to inverse square law

According to Beer-Lambert's law

Compare two methods from several distances.

Type of detector and field measurement condition	Distance from the source [m]	Measured data H*(10) dose-rate [mSv/h]	Measured and fitted data count-rate of the peak [cps]	Calculation with the correction factors	Activity [GBq]	Measurement uncertainty k=2 [%]
STEP OD-02 calibrated ion chamber, direct field	1,85	2,36	-	H*(10) to KERMA and KERMA coef.	74,9	21
	0,77	13,77	-		75,7	23
Symetrica Verifinder LaBr3 scinti. crystal, indicect field shielding 50mm lead	2,17	-	1183	inverse square distance and attenuation coef.	85,8	27
	0,86	-	7088		80,7	31

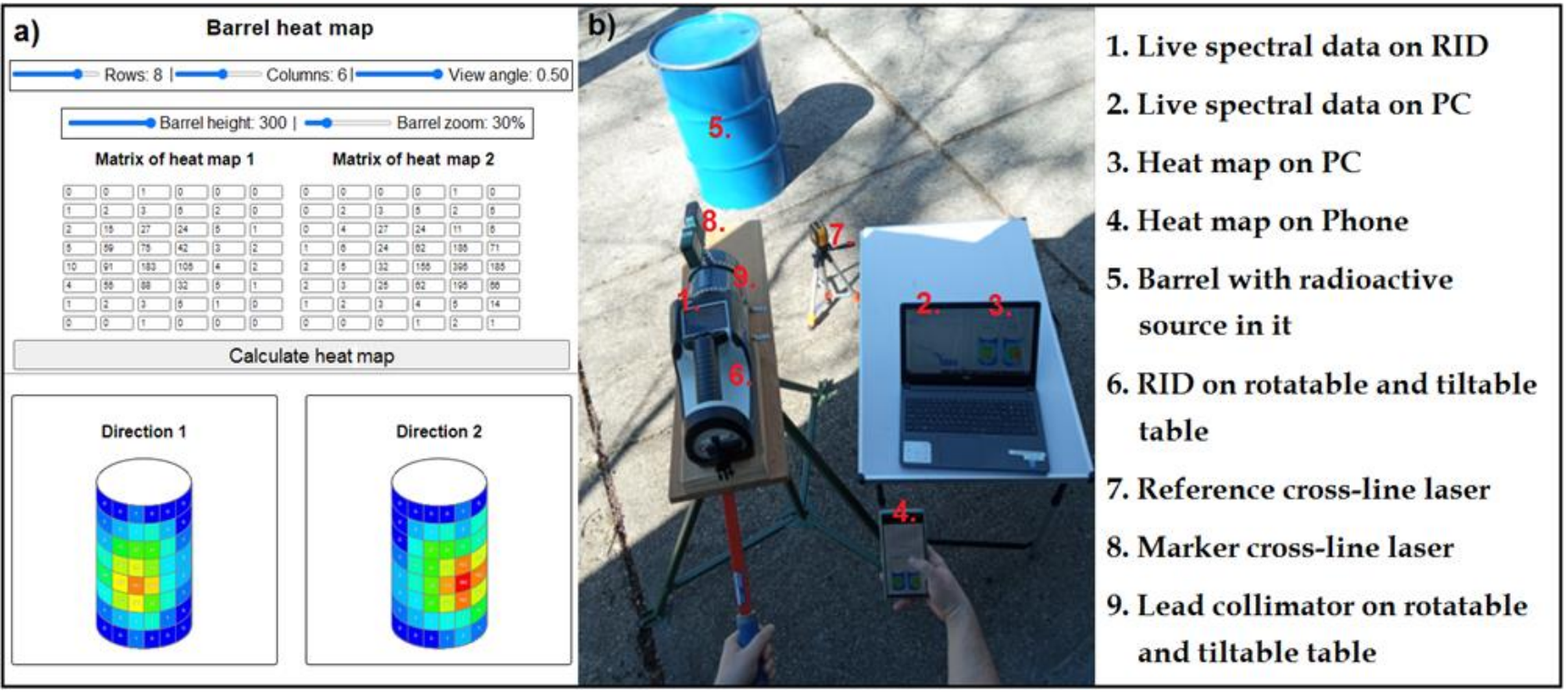


These confirm the correctness of both the distance and shielding / attenuation correction factors and formulas.

The concept of gamma „heat” map can help with the difficulties

Parts:

- „Gamma Camera” Experimental Setup
- self-developed, responsive - gamma „heat” map recording - web software (free)
  https://csalotzky.github.io/barrel-heatmap/



Features of the usage:

- With horizontal and vertical rotation the effect of angular deviation can be easily taken into account
- Gamma radiation visible only from the given solid angle
- Marker laser moves together with the orientation of the lead collimator, so marker cross-line moves on the barrel
- Standing reference laser cross-line helps to fulfill the grid/matrix of the heat map
- Gamma heat map recorded tile by tile
- More directions allow much better estimation in not well-known data and uncertainties

The experiences were also compared with X-ray imaging.

Thank you for your attention!

The following are also participated in the project: Csilla Csöme, Csaba Tóth, Nándor Kaposy, György Nagy, István Almási, András Kocsonya

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