Validation of In-situ Gamma-ray Spectrometry and sampling on highly contaminated area

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In situ gamma-ray spectrometry
(validation for flat geometry)
Basic principle

- IAEA TEC DOC 1092

where:
- $A_s =$ surface contamination (kBq/m$^2$)
- $N =$ peak area
- $N_b =$ background
- $t =$ spectrum collecting time, live time (s)
- $P_g =$ gamma photon emission probability (E, nuclide)
- $C_f =$ calibration factor (cm$^2$)

$$A_s (kBq/m^2) = \frac{10 \cdot (N - N_b)}{C_f \cdot t \cdot P_g}$$

Detector calibration factor

$$C_f = \frac{R_f}{A_s} = \left( \frac{R_f}{R_0} \right) \left( \frac{\Phi}{A_s} \right)$$

- **angular correction factor** – correction factor required to account for the detector angular response.
- **geometrical factor** – total photon flux density at the detector per unit concentration or deposition inventory of the radionuclide

**response factor** - net peak count rate due to a unit primary photon flux density of energy $E$ incident on the detector (normal to the detector face)

$R_i =$ net count rate
Angular correction factor

Angular correction factor $R/R_0$ as a function of Ge crystal length/diameter L/D ratio at three different energies for a downward facing detector for a uniform with depth source profile in the soil.
Theoretical model for photon flux calculation

\[ \Phi = \int_0^{\pi/2} d\theta \int_{h/\cos\theta}^{\infty} \frac{S_0}{4\pi r^2} e^{-r/\cos\theta} \cdot 2\pi r^2 \sin \theta \cdot e^{-h/\cos\theta} \cdot e^{-\mu \rho z/L} \, dr \]

\[ [\Phi] = \text{s}^{-1}\text{m}^2 \]

Air
\[ \mu_a = \mu_a(\mu/\rho)_a \]

Soil
\[ \mu = \mu(\mu/\rho) \]
\[ f(z), \text{ e.g.} \]
\[ f(z) = S_0/L \exp(-z/L) \]

Test with I-131

- Two different calibration of the detector
  - Mathematical using ISOCS
  - Empirical with point sources
- Control site is a simulated homogeneous surface 20m x 20m
  - 441 pieces I-131 source were distributed, total A = 2.460 (50) MBq
  - Pattern 1m x 1m net
“Source” preparation

- The $^{131}$I reference solution was spiked into the ink by gravimetric dilution (4.1 MBq)
- 450 pc. 5x5cm size source were printed
- 29 randomly selected source were tested for homogeneity
- The test site was installed on the dedicated military exercise field

Homogeneity test of 29 piece randomly selected sources, by gamma-ray sp.

Average 7071 Bq
SD 174 Bq
RSD 2.5%
Results of in situ validation for I-131

<table>
<thead>
<tr>
<th>Method</th>
<th>Results, MBq</th>
<th>U, % (k=1)</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical</td>
<td>2.71</td>
<td>11</td>
<td>Concrete</td>
</tr>
<tr>
<td>ISOCS</td>
<td>2.52</td>
<td>10</td>
<td>Concrete</td>
</tr>
<tr>
<td>Numerical</td>
<td>2.63</td>
<td>12</td>
<td>grassland</td>
</tr>
<tr>
<td>ISOCS</td>
<td>2.40</td>
<td>10</td>
<td>grassland</td>
</tr>
<tr>
<td><strong>Target value</strong></td>
<td><strong>2.46</strong></td>
<td><strong>4</strong></td>
<td></td>
</tr>
<tr>
<td>Repeatability</td>
<td>3.5 %</td>
<td>From 3 measurements</td>
<td></td>
</tr>
<tr>
<td>Reproducibility</td>
<td>5.7 %</td>
<td>From 2 installations</td>
<td></td>
</tr>
</tbody>
</table>
Remarks

- The results have good agreement but the flat distribution is an "easy" geometry
- The recommended reproducibility 50% (TEC DOC 1092)
- There is no significant difference between the "urban" surface and "grassland"
- The numerical approach has a little systematic overestimation
- Next step: to develop a method for profile validation (in near future)

Off site monitoring of the radioactivity

- Nuclear accident
- Terror attack
- Radiation incident
- Environmental pollution by industrial activity
- Regular environmental control
Off site monitoring of radioactivity
(methods and tools)

- Airborne exploration
- Surface exploration
  - route monitoring
  - gamma dose rate measurement
  - in-situ gamma spectrometry
  - sampling
  - and sample measurement on field
- Data evaluation and interpretation

Airborne exploration

- Special high sensitivity detector system with cosmic ray compensation
- Continuous data collection
- GPS location
- Data presentation by GIS
Results of the airborne scanning

- 40 m elevation
- Gamma intensity map
- No any nuclide specific information

Surface exploration

- Two detector systems
  - sensitive but short time constant (for searching) 3"x3" NaI, LaBr, plastic (gross gamma information)
  - gamma dose rate measurement (non paralyzable equipment)

- GPS, GIS
- (Sampling tools)
In situ gamma-ray spectrometry

General task: Identification of isotopes

- HPGe detector system
  - fast electronics
  - 25-40 % relative efficiency
  - 1800-3600 sec counting time
  - 1 m above the surface

- Prerequisite
  - calibrated detector
  - check list (system parts, battery, GPS, documentation tools)

  **handheld radiation monitors**
  (surface contamination monitor, gamma dose rate monitor, personal dosimeter)

  - decontamination tools
  - Map and task description

Sampling on highly contaminated area

- Sampling plan (based on the preliminary aerial and surface survey)
  - Goal of the sampling
  - Analysis to be carried out
  - Radiation safety (risk analysis or assessment)
  - Sample transfer and custody

- Sampling team
  - Team leader
  - „Clean“ person (administrator)
  - Assistant
  - „Dirty“ person (who will perform the sampling)
  - Control persons at the border of the contaminated area

- Prerequisite
  - check list (system parts, battery, GPS, documentation tools)
  - personal dosimeter

  **handheld radiation monitors**
  - decontamination tools
General rules on the contaminated area:

1. Each operation should be practice under inactive conditions!!!
2. Think twice what you are going to touch!!!
Results

Distribution of I-131 by measurements of samples

Grass samples

Bq/kg (original)

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Thank you for attention!