Measurements with the Mobile laboratory of the Atomic Energy Research Institute

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The Mobile laboratory of the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute

- The mobile laboratory is a Volkswagen Transporter (built in 1990, weight 2400 kg)
- 1913 cm³ Otto system boxer engine, producing 57 kW
- SYNCRO inclination
- 1 extra battery for the instruments, the engine charges the battery, or it is chargeable from the main electricity network
The requirements of the effective radiological environmental monitoring

- Fast reaction
- Complex dissection methods using at the same time
- Mobile – portable instruments
- Wide measuring range
- Reliable measurements – the same quantity determination with different measuring instruments
- Autonomous functioning – in situ evaluation

- The mobile laboratory’s measurement results assist the decision – making prepare
- The measurements purposes is to forecast the probable irradiation chargeing from the natural and fall – out gamma – irradiation isotopes in the KFKI campus
The environmental monitoring methods of the mobile laboratory

- Route monitoring
- In-situ gamma spectrometry
- Sample (soil, plant, liquid) assay with gamma spectrometry
- Dose rate measurements
- Atmospheric radioactive concentration measurements
- Personal dosimetry
Scheme of the monitoring system
The equipments of the mobile laboratory

- The mobile laboratory equipped with:
  - GPS
  - Notebooks (3)
  - Inspektor
  - Canberra 2020 HpGe detector
  - BNS 98 dose rate meter
  - nanoSPEC dose rate, cps, spectrum, etc. meter
Measurements with the nanoSPEC instrument
A handheld gamma spectroscopy system

- The nanoSPEC is a complete gamma spectroscopy system, including multichannel analyzer, amplifier, high voltage power supply, memory and an integral pin scintillation detector
- With the nanoSPEC we can measure:
  - Dose rate
  - Count rate
  - Live spectrum display
  - Nuclide identification

The energy calibration is easy with the built-in library, we are using $^{137}\text{Cs}$ source
Route monitoring

- The BNS 98 dose rate meter measures the actual dose rate and the GPS allocates the mobile laboratory’s position.
- The data transferred to the main notebook and the route monitoring programme represent the position and the actual dose rate.
Lost radioactive source exploration exercise in the KFKI campus

Radioactive source

Increased dose rate level
1152 nGy/h

Increased dose rate level
452 nGy/h

The dose rate level was normal background
~ 100 nGy/h

Mobile laboratory’s route
Lost radioactive source exploration
This is how we do...
The triangulation method

The background dose rate level is about 100 nGy/h
b, D₁, D₂ are commensurable
a=???

\[ a = \left[ \frac{b^2}{(D_2/D_1 - 1)} \right]^{1/2} \]

The radioactive source might be settled right or left handside of the van.

Actual dose rate level
Mobile laboratory’s route

Radioactive source

D₁
D₂
b
c
a
Lost radioactive source exploration
This is how we do...

\[
A = \hat{N}_i \cdot \frac{d\Gamma}{\epsilon_i D_i \Omega_i} \quad i = 1, 2
\]

with
- \(A\) activity
- \(\hat{N}_i\) net count rate at detector position \(i\)
- \(\epsilon_i\) intrinsic efficiency
- \(D_i\) emission probability
- \(\mu_{si}, \mu_s\) attenuation coefficients of air and soil
- \(d_i, d_s\) detector-soil surface distance
- \(d_x\) source - soil surface distance
- \(\Omega_i = \frac{\pi r^2}{(d_s + d_i)^2}\) solid angle
- \(r\) detector radius

Substituting \(a^2 = \frac{\hat{N}_1 \cdot e^{\mu_A(d_1 - d_2)}}{\hat{N}_2}\) leads to a simple quadratic equation

\[
(a^2 - 1)d_i^2 + 2a^2(d_i - d_s)d_i + a^2d_i^2 - d_s^2 = 0
\]

that can be solved into

\[
d_{x(1,2)} = \frac{-2(a^2d_i - d_s) \pm \sqrt{4(a^2d_i^2 - d_s^2) - 4(a^2 - 1)(a^2d_i^2 - d_s^2)}}{2(a^2 - 1)}
\]

therefore

\[
d_{x(1)} = \frac{d_2 - ad_1}{a - 1}
\]

with \(a = \sqrt{\frac{\hat{N}_1}{\hat{N}_2}} \cdot e^{\mu_A(d_1 - d_2)/2}\)

and

\[
d_{x(2)} < 0
\]

Given \(e^{\mu_A(d_1 - d_2)} \approx 1\) follows

\[
d_2 = \sqrt{\frac{\hat{N}_1}{\hat{N}_2}} \cdot d_1
\]

\[
d_{x(1)} = \sqrt{\frac{\hat{N}_1}{\hat{N}_2}} \cdot \frac{\hat{N}_1}{\hat{N}_2} - 1
\]
Calibration & angle dependence determination of the BNS 98 dose rate meter

- The calibration and angle dependence and mobile laboratory shielding determination of the BNS 98 was made from different distances and angles, with a Cs-137 radioactive source
- The reference was a calibrated UMO dose rate meter
- $D^* = DCF_{Cs-137} * A/r^2$
The latest on line route monitoring development

- A new central environment control system has been developed at the Environmental Protection Service (EPS)
- One of the goals of this development is to simultaneously display the BNS 98 dose rate meter data and the data provided by the non-mobile stations
- This development is made possible by a wireless internet connection between the main server and the Mobile laboratory

Snapshot of the new central environment control system monitor (Stations 16 to 18 are not connected)
In the picture the route (coloured dots 1 to 20) and the dose rates measured along this route are demonstrated in the case a hypothetical radioactive orphan source is placed in the location marked in the picture.
In – situ gamma spectrometry

- For fast qualitative & quantitative assay of the environmental irradiation
- Datastore & immediately evaluation
- Conversion to radionuclide concentration
- The fall – out radioactive contamination depth in the soil
  - Inspector (analiseing instrument)
  - Canberra GeLi detector:
    - $V_a = 93\, \text{cm}^3$
    - Relative efficiency: 22.2% (1333 keV)
    - Resolution: 1.89 keV
    - Software: GENIE 2000
    - Liquid N$_2$ refrigerant
The measurement time is usually 2000 sec.

The evaluation is fast with the GENIE 2000.

The programme shows:
- Nuclid name
- Energy
- Activity concentration
- Dose rate
- Measurement failure
Efficiency determination of the In-situ gammaspectrometer

• The efficiency determination of the In-situ gammaspectrometer was made from different distances, with a I-131 radioactive source
• The decreasing dose rate are the same as the measured peak areas in %
• The decreasing has $r^2$ characteristics
Smuggling trends

- The smugglers mixing (put together) the illegal radioactive materials to the legal radioactive carriages.
- If the Pu mixed with Ba-133 or I-131 the scintillation detectors are not able to detect the low yield gamma lines of the Plutonium.
- The modern portable semiconductor gammasepectrometers can detect the Pu.

Scintillation detector Ba-133 & Ba-Pu mix spectrum

Portable Detective2 semiconductor in-situ gammasectrometer with electrical refrigeration
Sampling...

- The environmental samples assayed with in-situ gamma spectrometry
- The system (HpGe) has lead shielding
- For the laminated soil sampling we are using special tools, instruments

- Atmospheric radioactive concentration measurements:
  - Sampling from the external air space, using combined filter
  - The system can separate the organic and the aerosol attached radioactive iodine components
  - The aerosol filter measured with gamma spectrometry
  - Continuous air sampling in the contaminated area
Soil sampling

• A 1m depth horizontal soil sample was measured with the in-situ gamma spectrometer
• The sample was taken in the KFKI Campus
• The body of the Cs-137 was located 5-10 cm deep
• The average migration speed is ¼ cm/year
• To remediate the soil, only the aboveground soil removing is needed

After several years the migrating radioactive material assimilate with the soil components
Rubbed sampling

- For rubbed sampling we use the MSZ 19391/5.2.2 and MSZ 19391/F1 sampling standards
- The sampling area is 100 cm²
- The efficiency of the measurement (MSZ 19391/6):
  \[ X = (1 - \frac{A_2}{A_1}) \times 100 \]
- where \( A_1 \) & \( A_2 \) are the same area
- The sampling tool is a cotton wool mounted on a plastic handle
- The samples are measured by the in-situ gamma spectrometer & the Berthold LB low beta counter
Personal dosimetry

Whole body counter

PorTL reader

TLD-100, TLD 7776 cards

Harshaw 6600
In – situ radioactive iodine measurements in the human thyroid gland

- The radioactive iodine can get into the atmosphere from the Budapest Research Reactor and from the Institute of Isotopes Co., Ltd.
- The human body accumulate the radioactive iodine into the thyroid gland
- The samples from the nose is the first step to determinate the iodine incorporation

![Graph showing activity vs. time in stomach, thyroid, and whole body.](image)
In-situ radioactive iodine measurements

- The radioactive iodine can be measured in the human body with a lead shielded 40x40 mm NaI(Ti) scintillation detector.
Iodine profilaxis

• With stable iodine feeding – after iodine contamination – the accumulation can be reduced to the thyroid gland and the dose.
Determination of the NORM contamination of the Hungarian Coal Power Plants in the environment

• The NORM (Naturally Occurring Radioactive Material) can be produced by coal power plants
• The coal that burned in the power plant contains radioactive material
• The amount of the radioactive material can be higher than other places if the mined coal surrounded Uranium, Thorium and it’s daughter elements
• The coal burned in the stokehold, the radioactive material and the ash concentrated by filtering of the stack gas
• The filtered out radioactive material placed into the slurry near the coal power plants
• The radioactive radiation of the slurry can be much higher than the surrounding places
Determination of the NORM contamination of the Hungarian Coal Power Plants in the environment

Measurements were taken near the Hungarian coal power plants. Samples were collected from the slurry and the soil was measured with the nanoSpec and the in-situ gamma spectrometer. The dose rate level was generally three times higher than the average, the maximum value was 510 nSv/h.

The outmost activity concentration levels were measured near the coal power plant of Pécs. The coal that burned in the coal power plant of Pécs were mined in the Mecsek mountains. The coal contains Uranium and its daughter elements because the Uranium mines were situated near the coal mining areas.
Determination of the NORM contamination of the Hungarian Coal Power Plants in the environment

<table>
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<tr>
<th></th>
<th>K-40 (Bq/kg)</th>
<th>U-Ra-chain (Bq/kg)</th>
<th>Th-chain (Bq/kg)</th>
<th>Ru-106 (Bq/cm²)</th>
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<tr>
<td>Mátra</td>
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<td>16,77</td>
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<td>Lőrinc</td>
<td>328,19</td>
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<td>0,257</td>
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</table>
- Measuring
- In-situ gammaspectrometry
- Lost radioactive material exploration
- Sampling (SIRA)
- Route monitoring

Personal route monitoring
Quality management

- The EXEL table shows the actual calibration status of the measuring tools, like a desk calendar, it helps to update the tools
- Another EXEL table shows the daily actual activity level of the radionuclides
- The side by side measurements secure the accuracy (1. measuring tool, 2. calibrated measuring tool)
- With these equation the accuracy is commensurable and verifiable

\[ D^* = DCF \times A/r^2 \]
Future developments, accessories

- Mini portable removable minicar, model
- helicopter (UAV) & boat equipped with
- radiological measurement
- tools, infra camera, remote system,
- weather parameters measuring tools
- and data transfer communication systems
- Advantages:
  - Cheap
  - Portable with the mobile laboratory
  - Easy handling
  - Fast
  - Side by side measurements
  - The human radiation exposure is
  - minimal
  - The inaccessible targets are
  - approachable