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 Atomoic Energy Research Institute

- The mobile laboratory is a Volkswagen Transporter (bulit in 1990, weight 2400 kg)
- 1913 cm^3 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

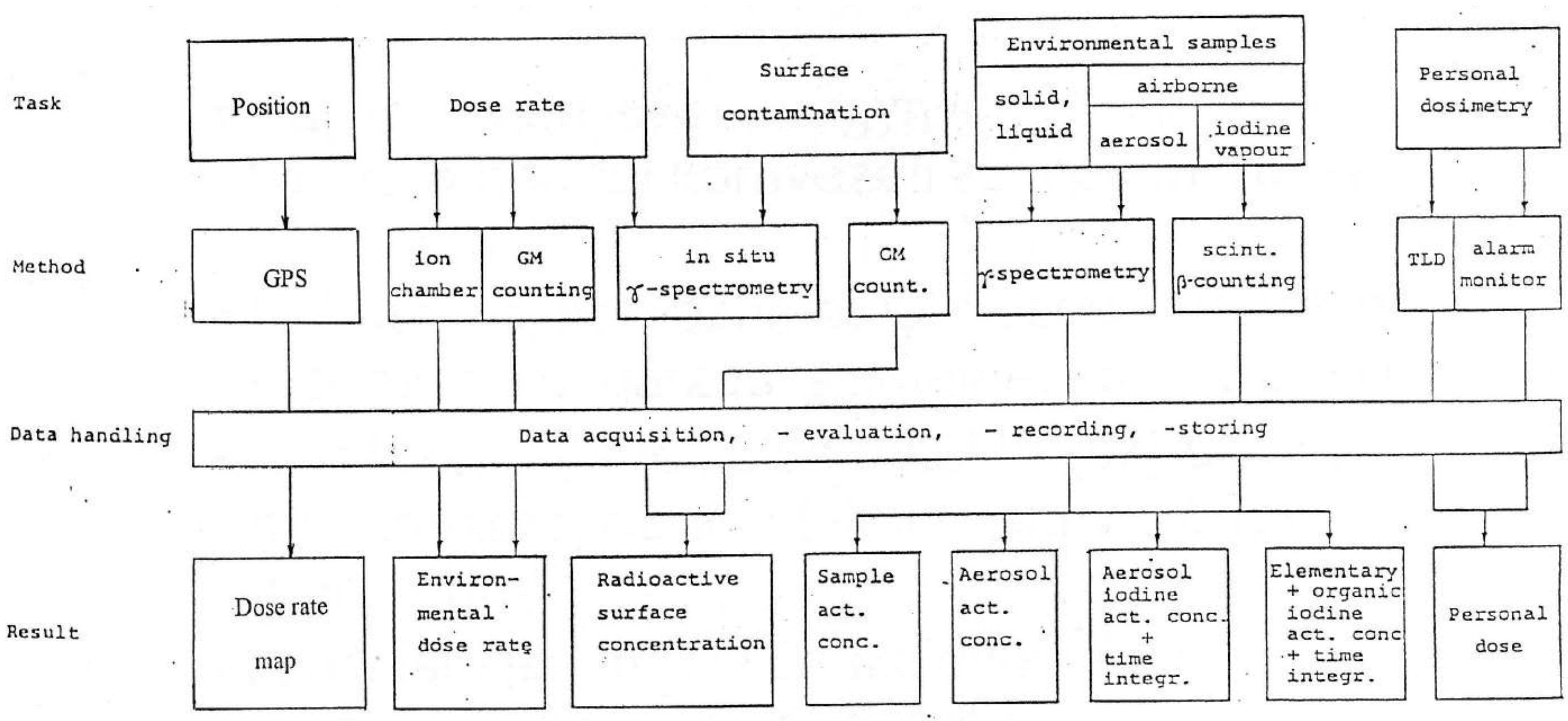
- Fast reaction
- Comlex dissection methods using at the same time
- Mobile – portable instruments
- Wide measuring range
- Reliable measurements – the same quantity determination with different measuring instruments
- Autonomous functioning – in –situ evaluation

- 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



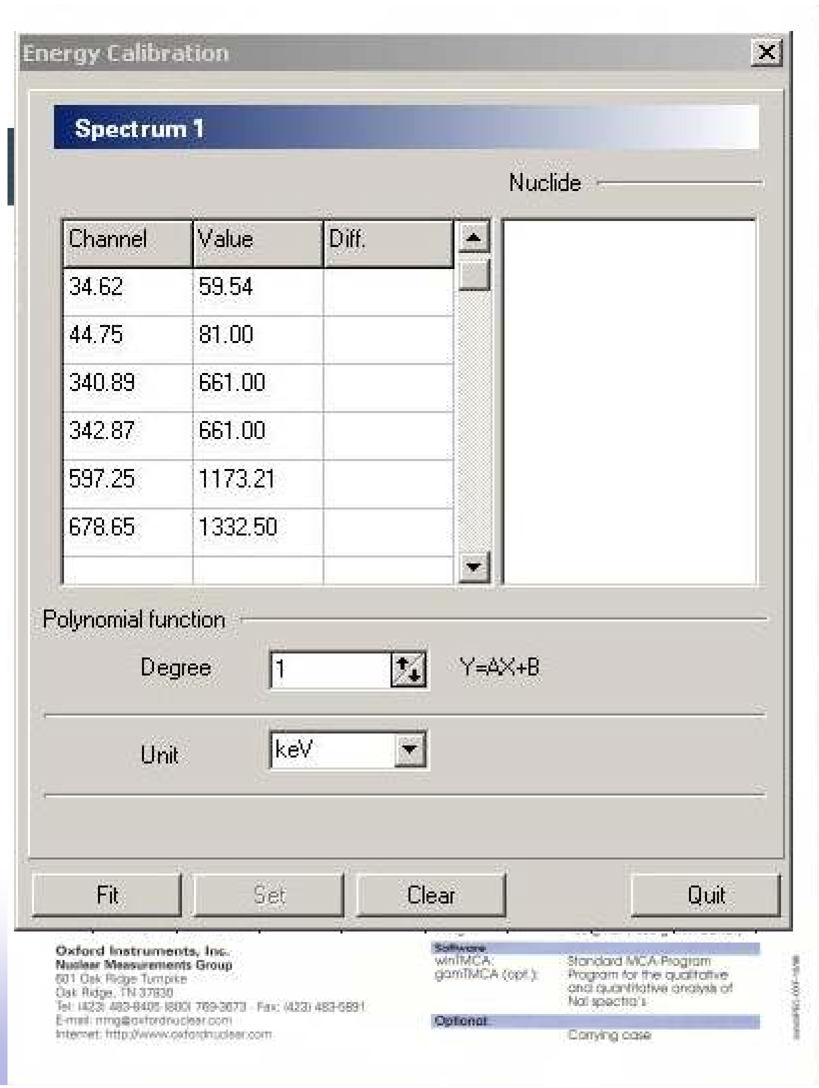
The equipments of the mobile laboratory

- **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

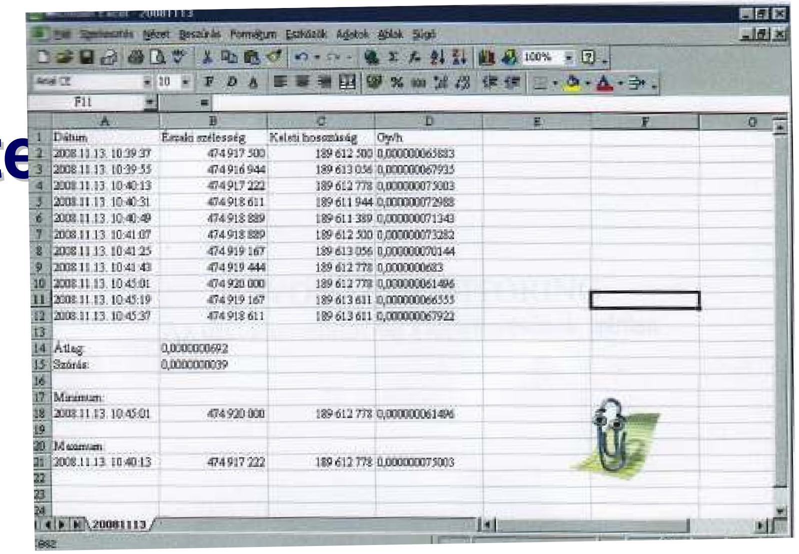
- **The nanoSPEC is a complete gamma spectroscopy sytem, including multichannel analyzer, amplifier, high voltage power supply, memory and an integral pin scintillation detector**
- **With the nanoSPEC we can measure:**
  - Dose rate
  - Count rate
  - Live spectrum display
  - Nuclide identification

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

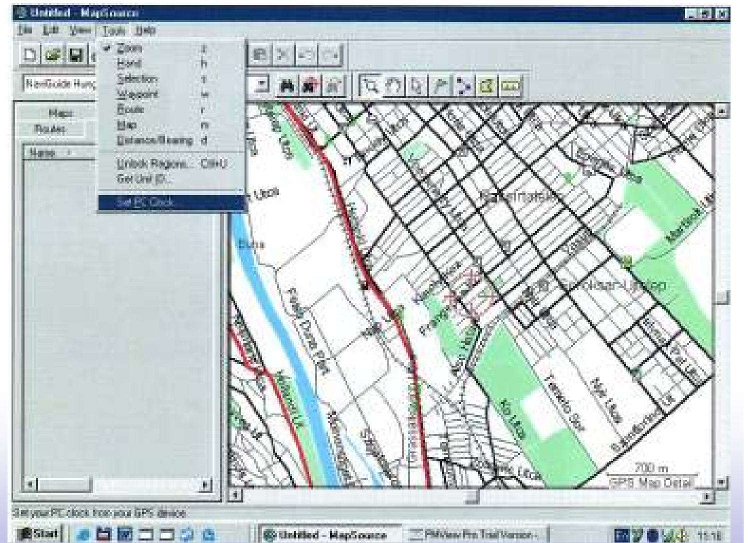


Route monitoring

- The BNS 98 dose rate meter measures the actual dose rate and the GPS allocates the mobile laboratory's position
- The datas transferred to the main notebook and the route monitoring programme represent the position and the actual dose rate



	A	B	C	D
1	Dátum	Északi szélesség	Keleti hosszúság	Gy/h
2	2008.11.13. 10:39:37	474 917 500	189 612 500	0,000000065833
3	2008.11.13. 10:39:55	474 916 944	189 613 056	0,000000067935
4	2008.11.13. 10:40:13	474 917 222	189 612 778	0,000000075003
5	2008.11.13. 10:40:31	474 918 611	189 611 944	0,000000072988
6	2008.11.13. 10:40:49	474 918 889	189 611 389	0,000000071343
7	2008.11.13. 10:41:07	474 918 889	189 612 500	0,000000073282
8	2008.11.13. 10:41:25	474 919 167	189 613 056	0,000000070144
9	2008.11.13. 10:41:43	474 919 444	189 612 778	0,0000000683
10	2008.11.13. 10:45:01	474 920 000	189 612 778	0,000000061496
11	2008.11.13. 10:45:19	474 919 167	189 613 611	0,000000066555
12	2008.11.13. 10:45:37	474 918 611	189 613 611	0,000000067922
13				
14	Átlag:	0,0000000692		
15	Szórás:	0,0000000039		
16				
17	Minimum:			
18	2008.11.13. 10:45:01	474 920 000	189 612 778	0,000000061496
19				
20	Maximum:			
21	2008.11.13. 10:40:13	474 917 222	189 612 778	0,000000075003



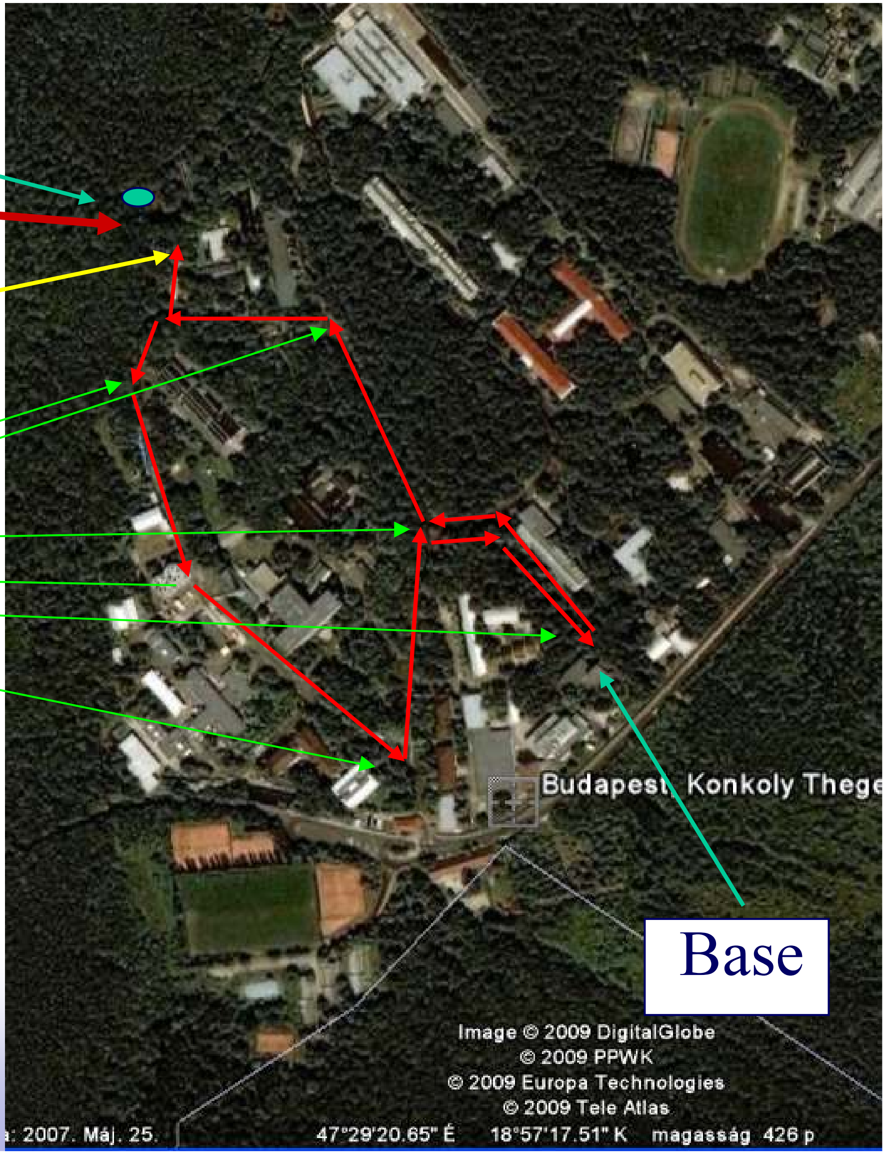
Lost radioactive source exploration exercise in the KFKI campus

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

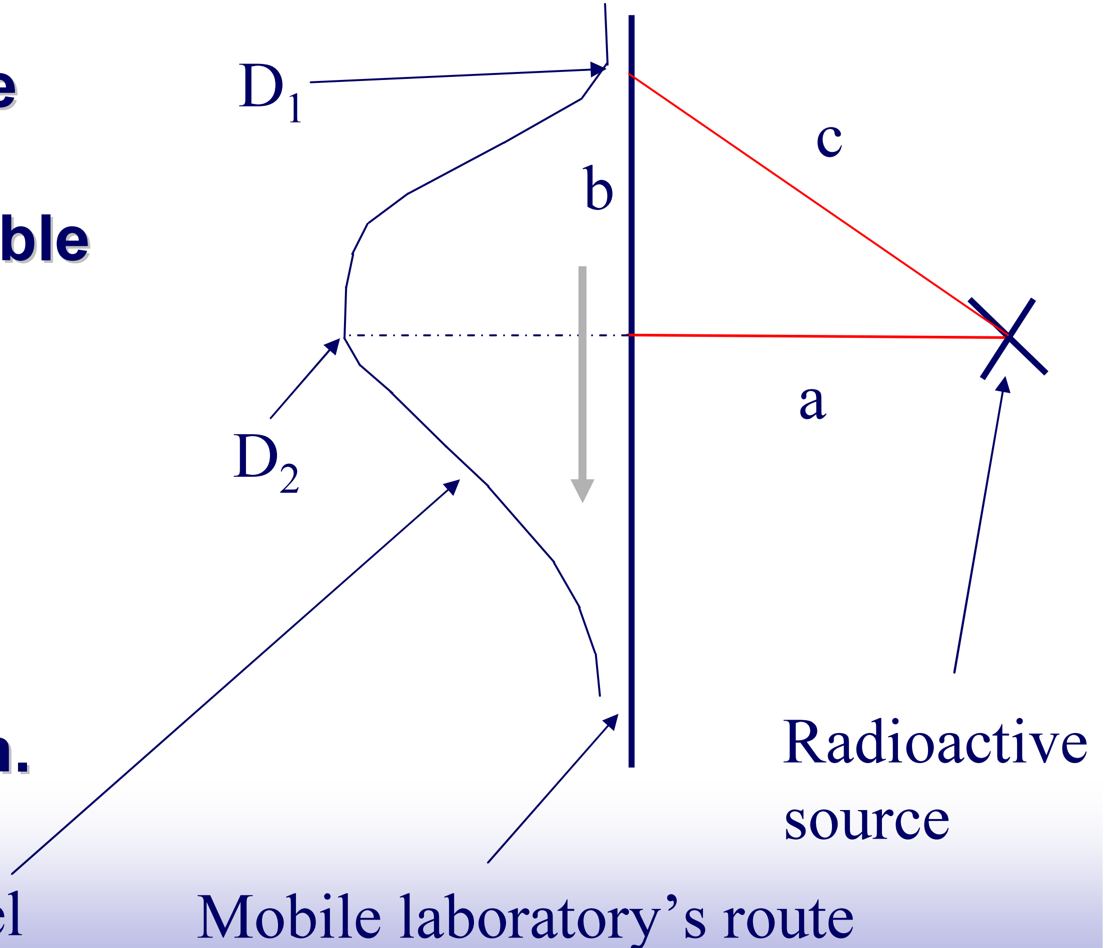
The background dose rate level is about 100 nGy/h

b, D_1, D_2 are commensurable

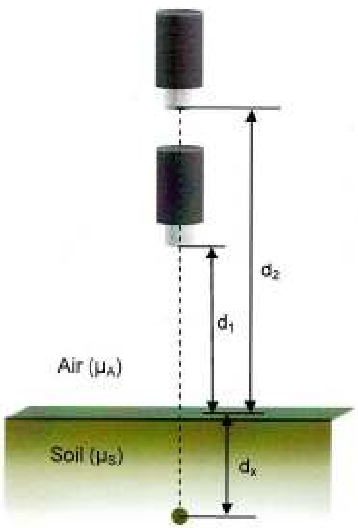
a=???

$a=[b^2/(D_2/D_1 -1)]^{1/2}$

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



Lost radioactive source exploration This is how we do...



$$A = \dot{N}_i \frac{1}{\varepsilon_{int} p_\gamma} \frac{4\pi}{\Omega_i} e^{(\mu_S d_X + \mu_A d_i)} \quad i = 1,2$$

with

A ....activity

$\dot{N}_i$ ....net count rate at detector position i

ε_{int}................................intrinsic efficiency

p_γ................................emission probability

μ_A, μ_S ________________ attenuation coefficients of air and soil

d_i ________________ detector-soil surface distance

dx................................source – soil surface distance

$\Omega_i \approx \frac{\pi r^2}{(d_x + d_i)^2}$ ....solid angle

r ....detector radius

$$1 = \frac{\dot{N}_1 (d_x + d_1)^2}{\dot{N}_2 (d_x + d_2)^2} e^{\mu_A (d_1 - d_2)}$$

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

$$(a^2 - 1) d_x^2 + 2(a^2 d_1 - d_2) d_x + a^2 d_1^2 - d_2^2 = 0$$

that can be solved into

$$d_{x(1,2)} = \frac{-2(a^2 d_1 - d_2) \pm \sqrt{4(a^2 d_1 - d_2)^2 - 4(a^2 - 1)(a^2 d_1^2 - d_2^2)}}{2(a^2 - 1)}$$

therefore

$$d_{x(1)} = \frac{d_2 - a d_1}{a - 1} \quad \text{with} \quad a = \sqrt{\frac{\dot{N}_1}{\dot{N}_2} \cdot e^{\mu_A (d_1 - d_2)/2}}$$

and

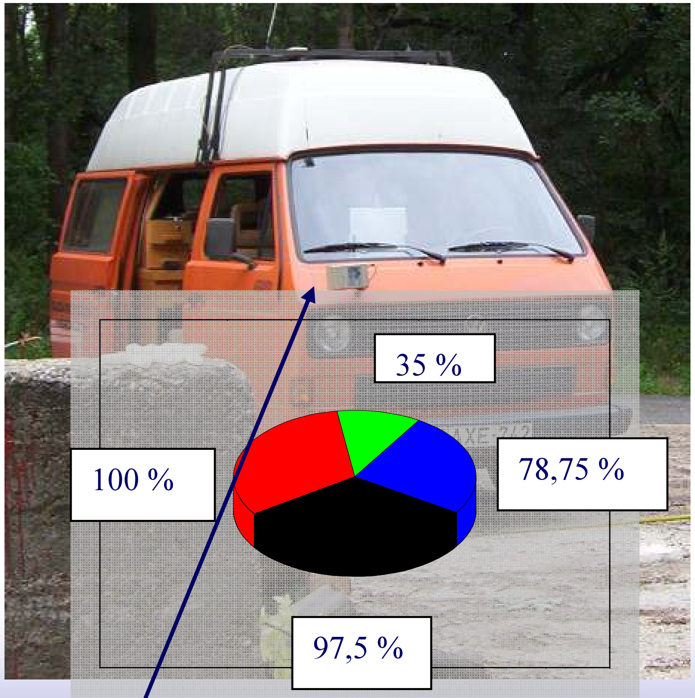
$$d_{x(2)} < 0$$

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

$$d_{x(1)} = \frac{d_2 - \sqrt{\frac{\dot{N}_1}{\dot{N}_2}} \cdot d_1}{\sqrt{\frac{\dot{N}_1}{\dot{N}_2}} \cdot -1}$$

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
- $D^{*}=DCF_{Cs\text{-}137}{*}A/r^{2}$

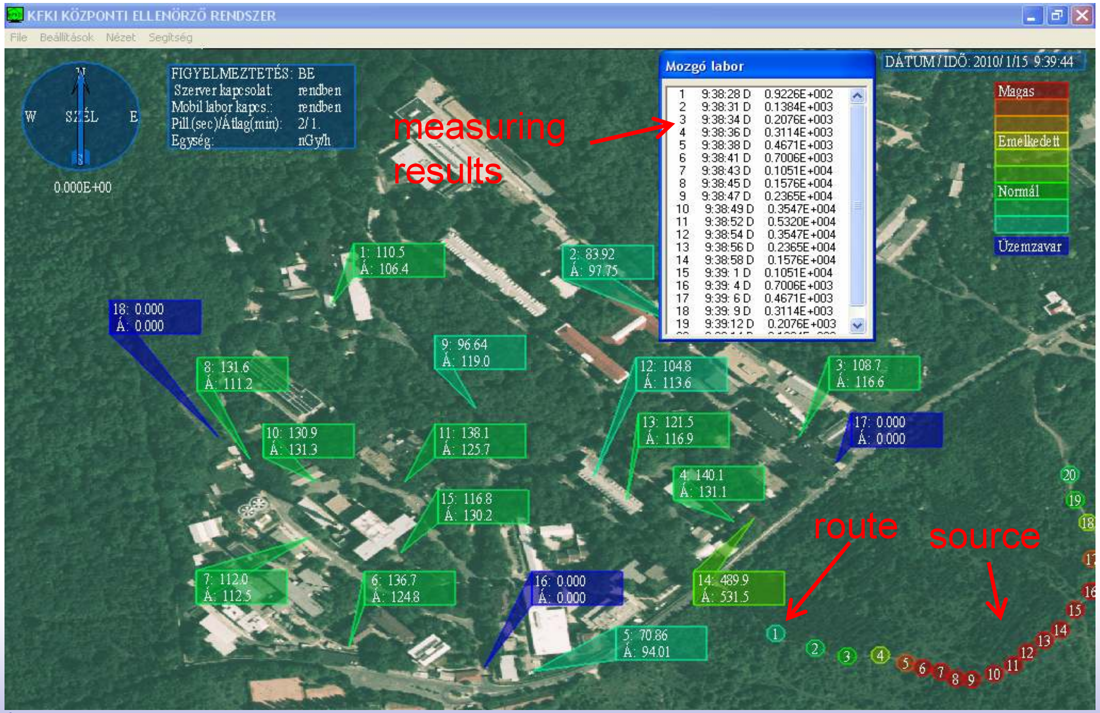


Sensible part

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

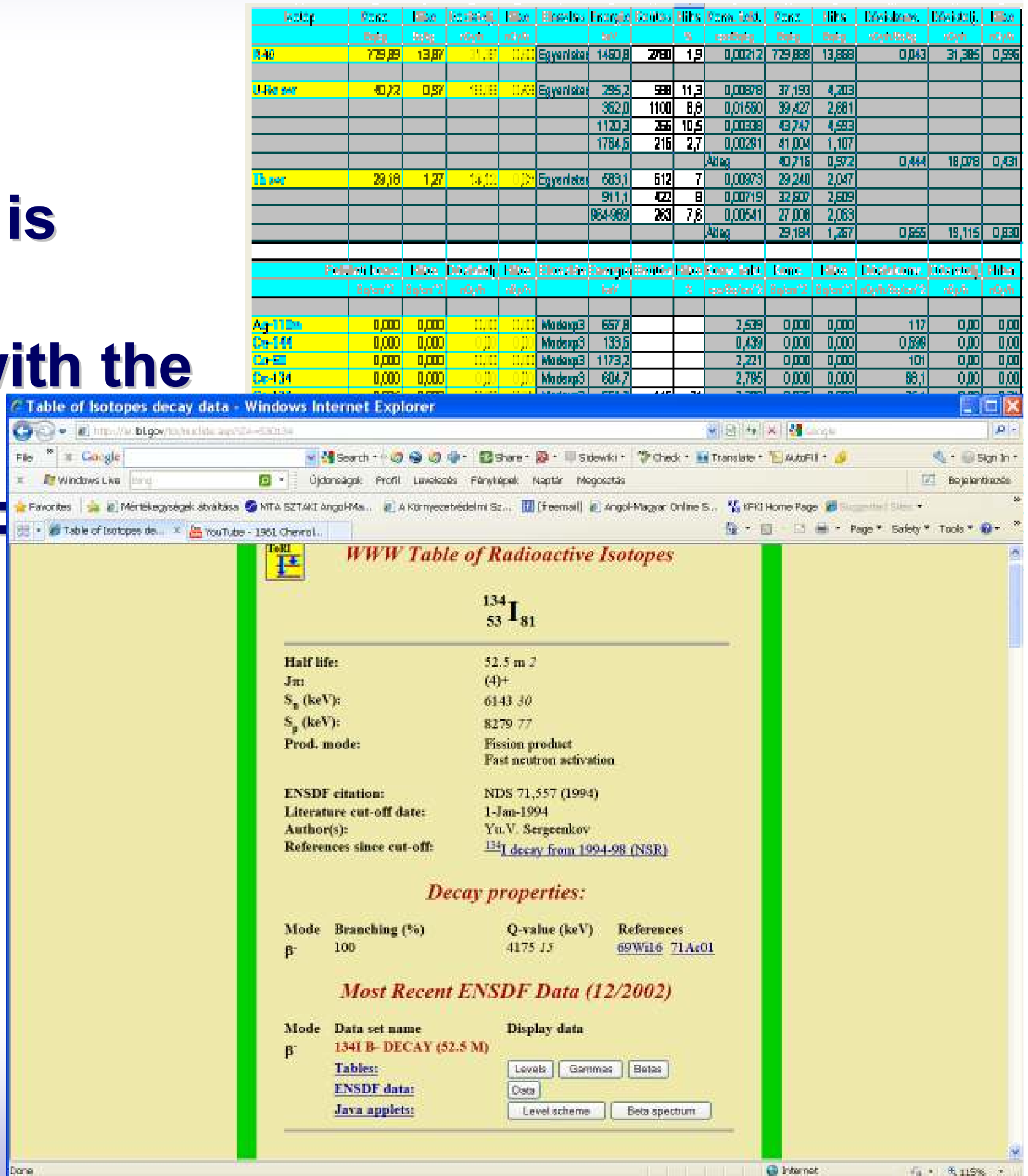


In – situ gamma spectrometry

- For fa
  irradi
- Datas
- Conv
- The fa
  soil
- Inspe
- Canb
  - V
  - Re
    (1
  - Re
  - Sc
  - Li

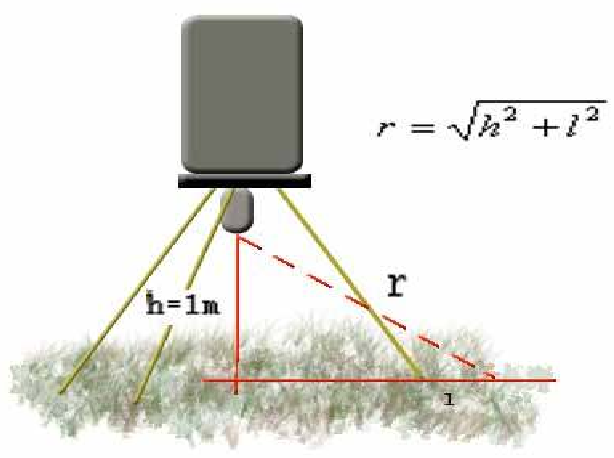
Measurement evaluation

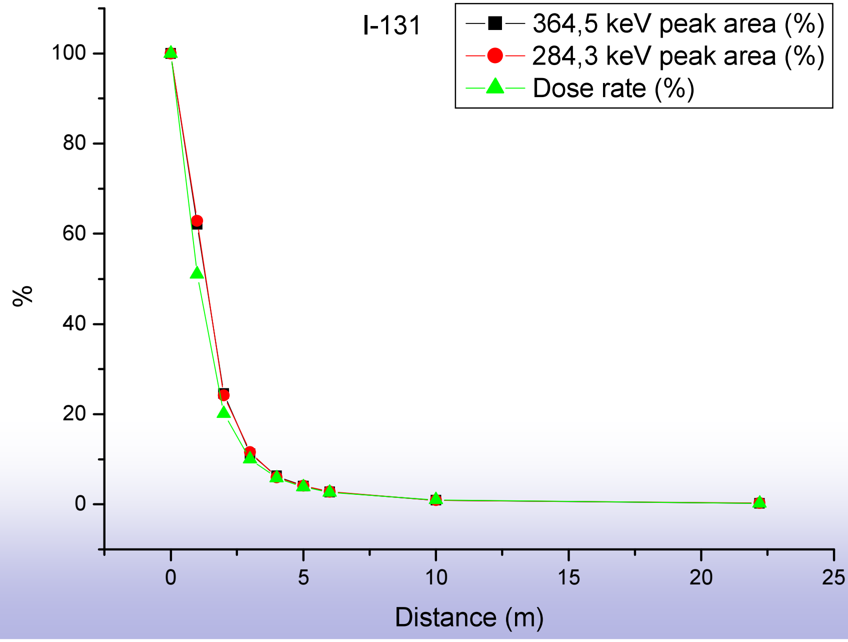
- **The measurement time is usually 2000 sec**
- **The evaluation is fast with the GENIE 2000**
- **The programme shows:**
  - Nuclid name
  - Energy
  - Activity concentration
  - Dose rate
  - Measurement failure



Efficiency determination of the In-situ gammaspectrometer

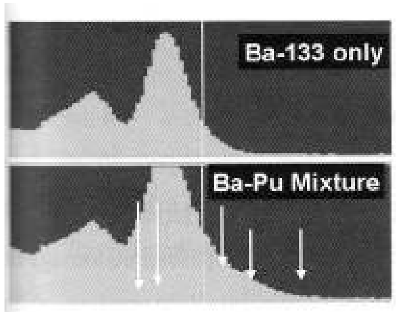
- The efficiency determination of the In-situ gammaspectrometer was made from different distances, with a I-131 radioactive source
- The decreasing dose rate are the same as the measured peak areas in %
- The decreasing has r^{-2} charachteristics



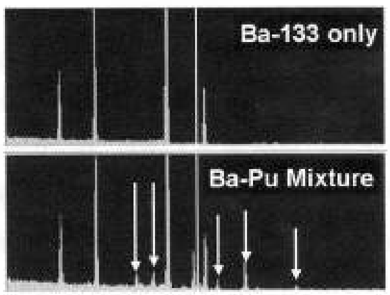


Semiconductor VS. Scintillation detector
Smuggling trends

- **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 gammasepctrometers can detect the Pu**



Scintillation detector Ba-133 &Ba-Pu mix spectrum



Semiconductor detector Ba-133 &Ba-Pu mix spectrum

Portable Detective2 semiconductor in-situ gammasectrometer with electrical refrigeration

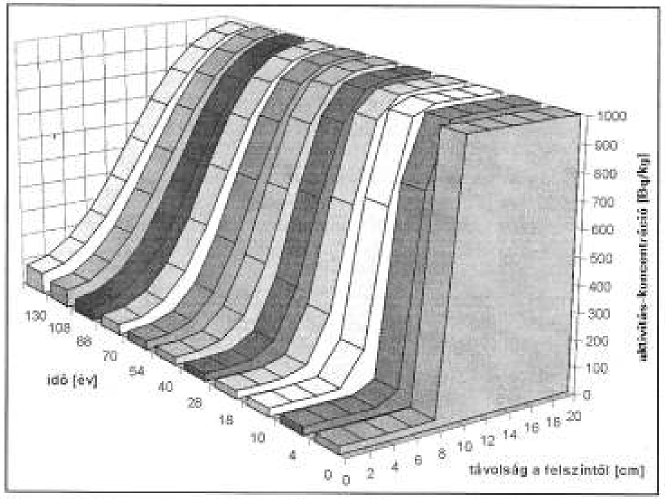
Sampling...

- **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**

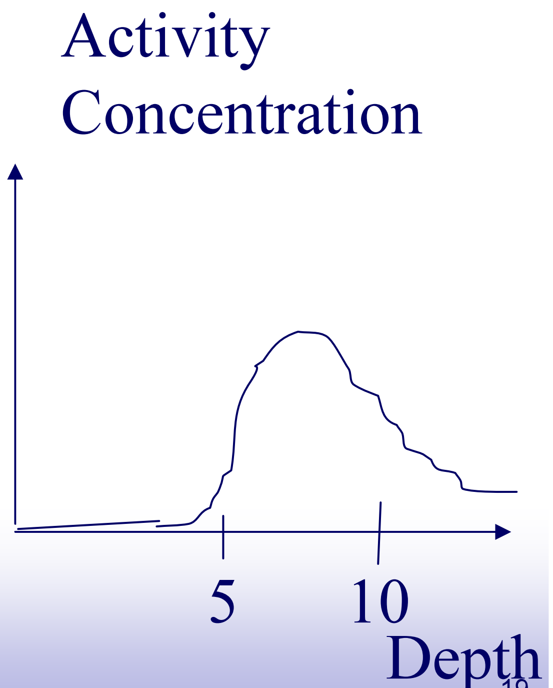
- **Atmospheric radioactive concentration measurements:**
  - Sampling from the external air space, using combined filter
  - The system can separate the organic and the aerosol attached radioactive iodine components
  - The aerosol filter measured with gamma spectrometry
  - Continous air sampling in 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 cm^2
- The efficiency of the measurement (MSZ 19391/6):

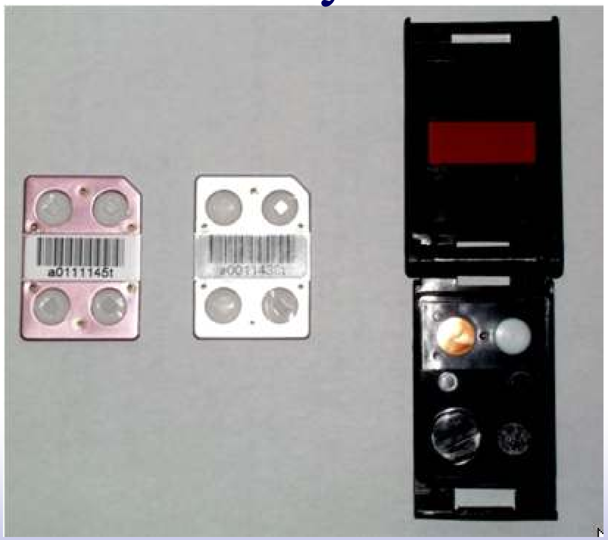
$$X=(1-A_2/A_1)*100$$

- 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

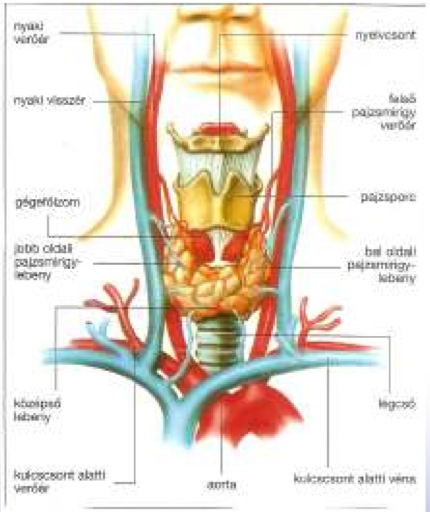


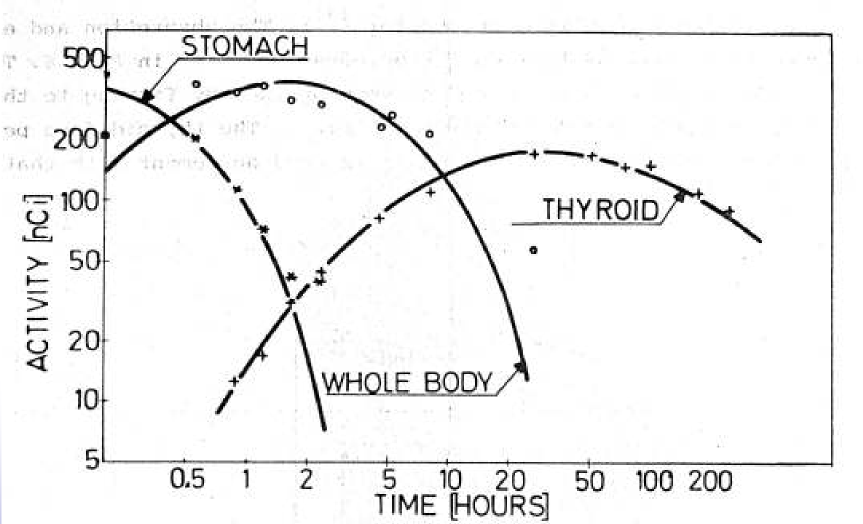
TLD-100, TLD 7776 cards

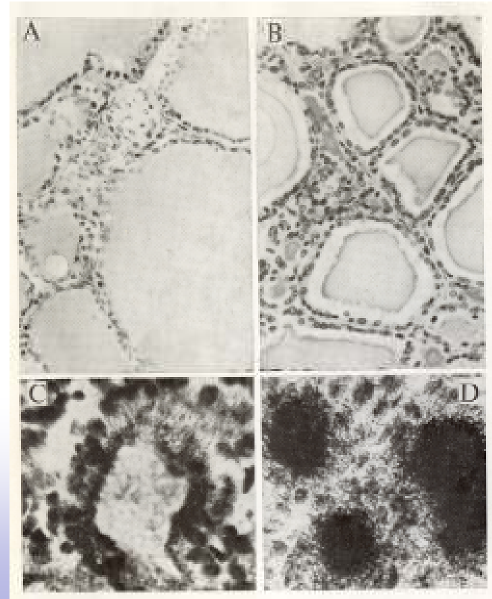
Harshaw 6600

In – situ radioactive Iodine measurements in the human thyroid gland

- The radioactive Iodine can get into the atomosphere 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

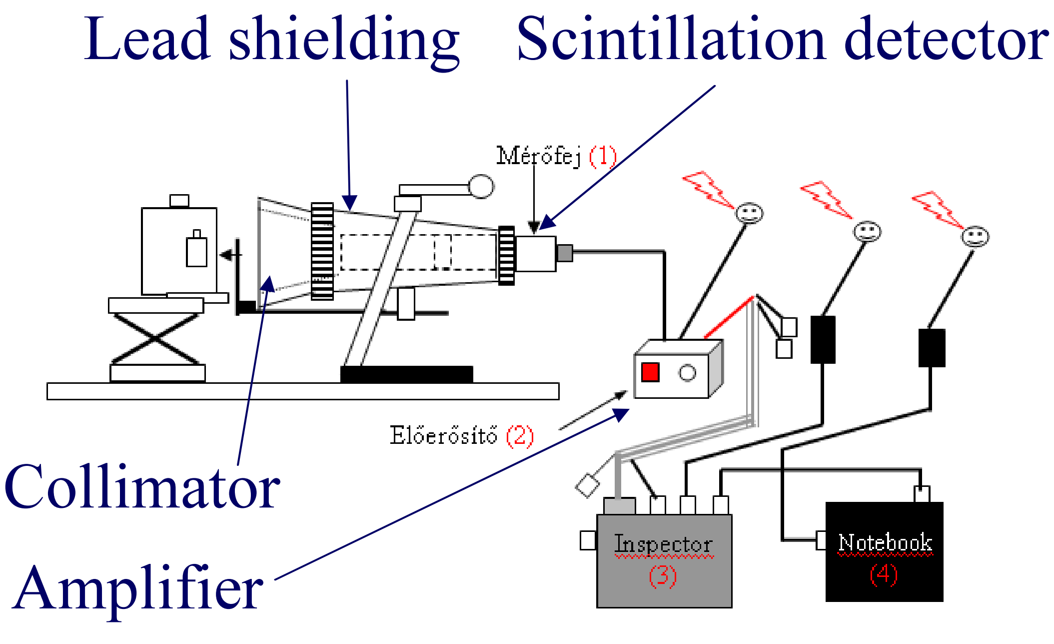






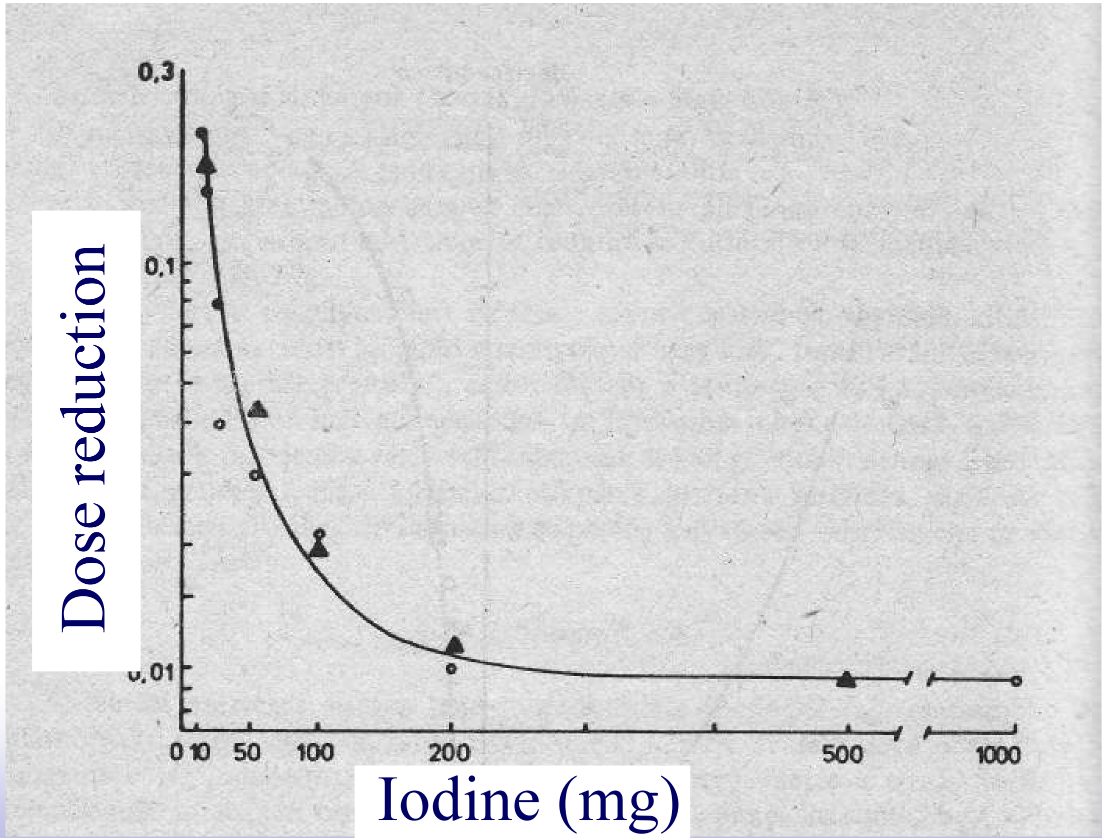
In-situ radioactive Iodine measurements

- 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

	K-40 (Bq/kg)	U-Ra-chain (Bq/kg)	Th-chain (Bq/kg)	Ru-106 (Bq/cm^2)
Mátra	439,73	16,77	0,92	0,258
Pécs	729,89	40,72	29,18	0,305
Lőrinc	328,19	26,58	17,81	0,257

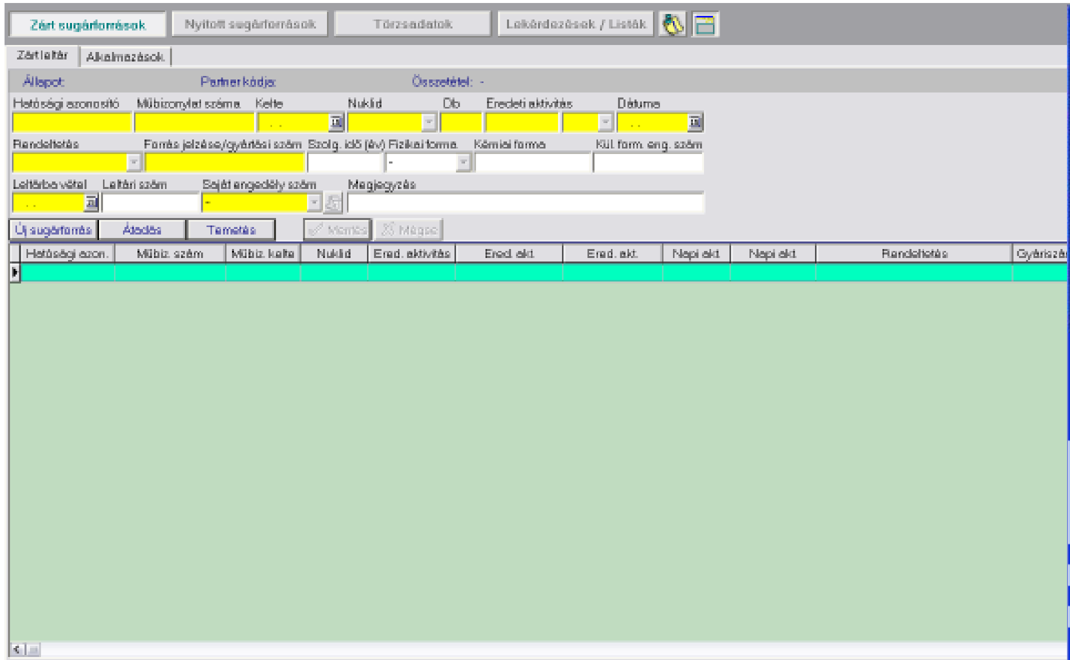
- M
- In
- L
- S
- R
- N

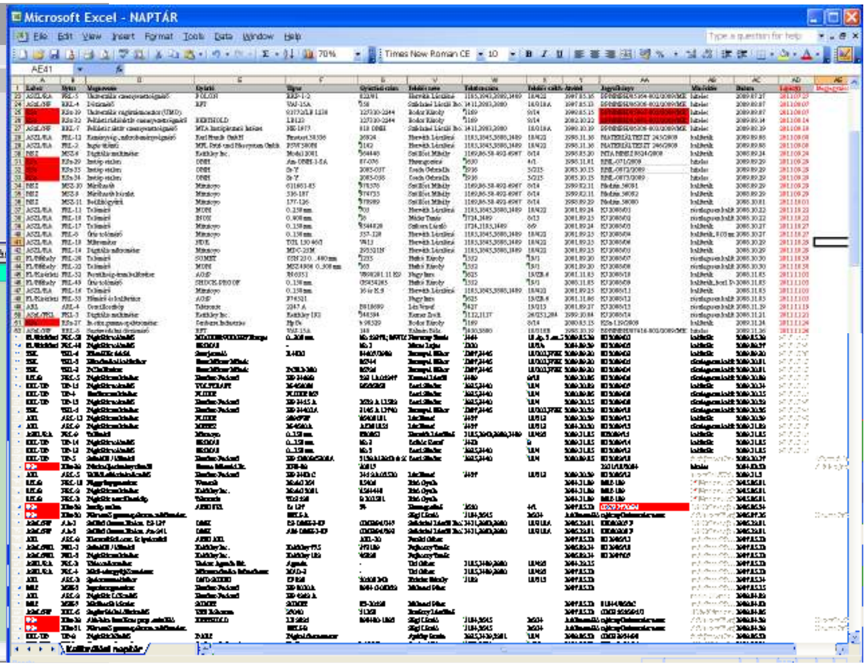
Personal route monitoring

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 accurancy (1. measuring tool, 2. calibrated measuring tool)**
- **With these equation the accurancy is commensurable and verifiable**

$$D^* = DCF^* A / r^2$$





Future developments, accessories

- Mini portable remotable 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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