Update on gamma spectrometry at DTU Risø

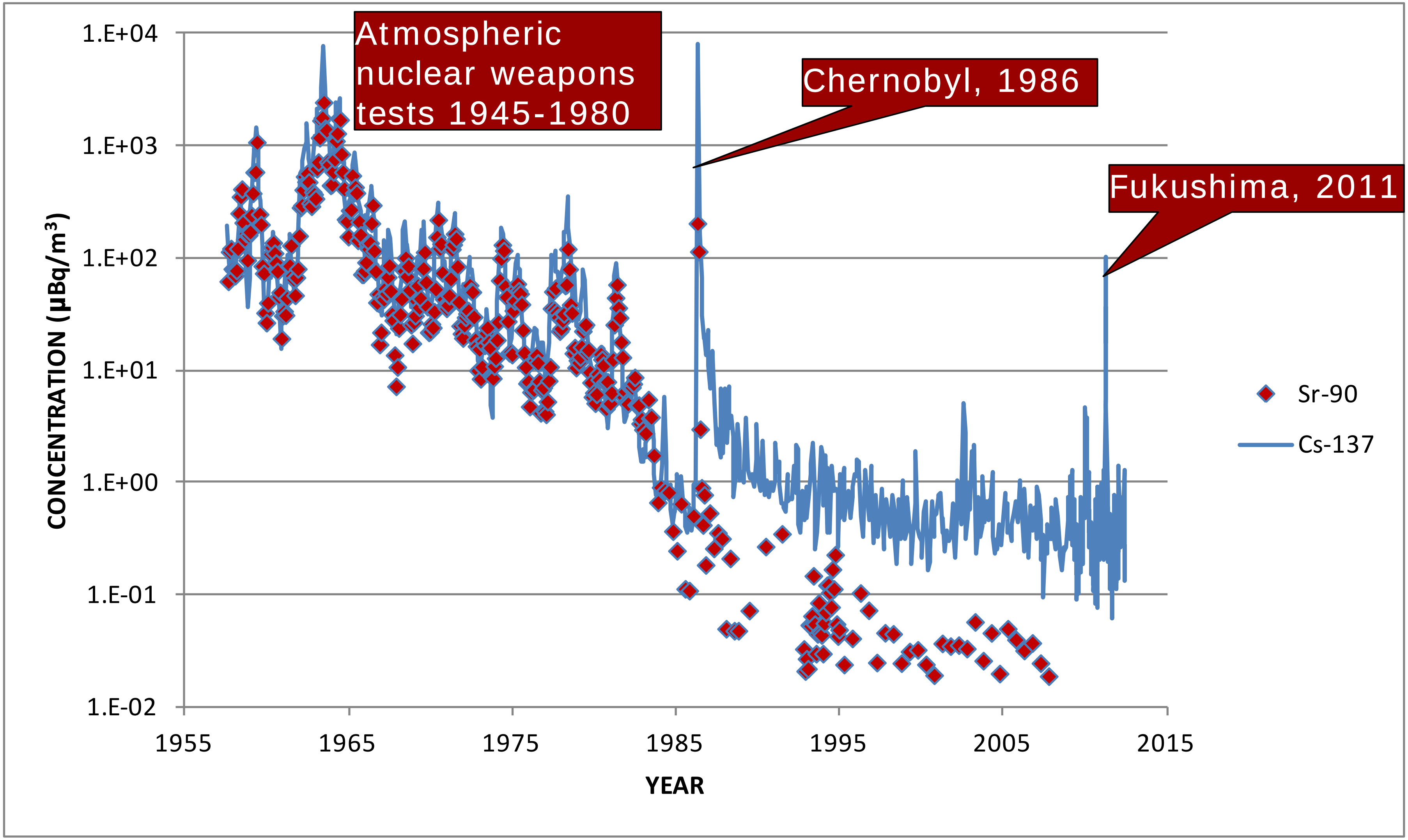
Sven P. Nielsen

Aerosols

- Monitoring of radioactivity in air is based on aerosol collectors located in Haderslev, Allinge and Risø.
- Air is sampled at flow rates of 500-2000 m^3/h through organic filters retaining particles
- Filters are changed weekly and analysed for short-lived radionuclides first and later for longer lived radionuclides, particularly ^{7}Be, ^{210}Pb, ^{90}Sr, ^{137}Cs.


CANBER

Radioactivity in air at Risø



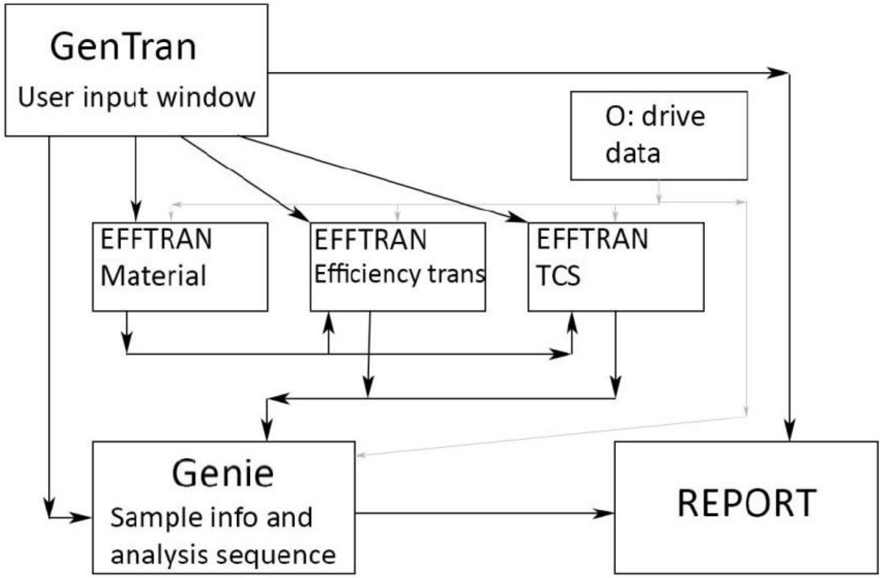
Gamma laboratory

Sample Geometries

- 1-L Marinelli beaker (0.6-1 L)
- 210 mL cylindrical beaker (20-200 mL)
- 400 mL cylindrical beaker (20-390 mL)
- 25 mL Petri dish (5, 10 and 15 mL)
- 70 mL Petri dish (20-65 mL)
- 10 mL vial (range 1-8 mL)
- 2 mL vial (range 0.2-2 mL)

Gamma spectrum analysis

- Analyses of gamma spectra from routine samples are based on Genie2000 combined with software for efficiency transfer and true coincidence summing corrections (EFFTRAN/MEFFTRAN/WEFFTRAN, Vidmar, 2005). EFFTRAN is used for cylindrical sample geometries, MEFFTRAN for Marinelli geometries, and WEFFTRAN for vial geometries used in well-type detectors.
- EFFTRAN/MEFFTRAN/WEFFTRAN are used for efficiency transfer (Vidmar, 2005) and true coincidence summing correction (Bruggeman et al, 2014; Vidmar et al, 2011) while GENIE2000 is used for peak search, peak area calculation, background correction, nuclide identification and activity/MDA calculation.
- Data flow between Genie2000 and EFFTRAN/MEFFTRAN/WEFFTRAN is handled by GenTran software (Markovic) that provides an interface between the user and the Genie2000/EFFTRAN calculation routines. GenTran controls the flow of data between different parts of the software routines enabling fast spectrum analysis processes and reducing the risk for user input errors.
- This setup provides maximum flexibility for analyzing samples of varying geometries, volumes and matrices and ensures good quality of analytical results.



Flowchart for analysis steps controlled by GenTran

Example: I-125 in urine

- Intakes of I-125 are monitored by gamma analyses of urine samples
- Data on TCS is incomplete for I-125, available for gamma energy (35 keV), but not for X-rays (27 keV, 31 keV)
- Thus only data on 35 keV is used for reporting

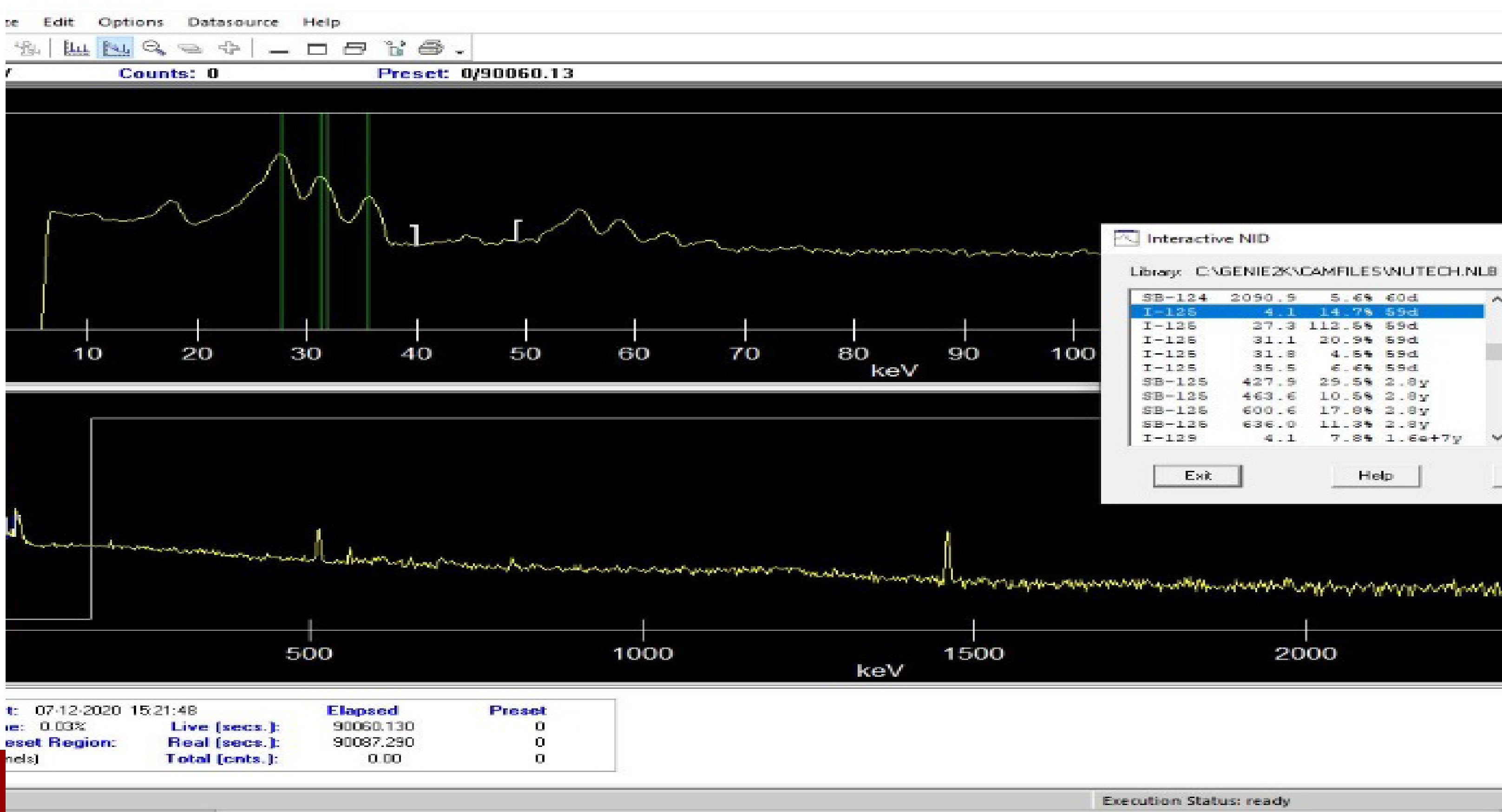
***** N U C L I D E   I D E N T I F I C A T I O N   R E P O R T *****

Sample Title:
Nuclide Library Used: C:\GENIE2K\CALFILES\EFFTRAN.NLB

.... IDENTIFIED NUCLIDES ....

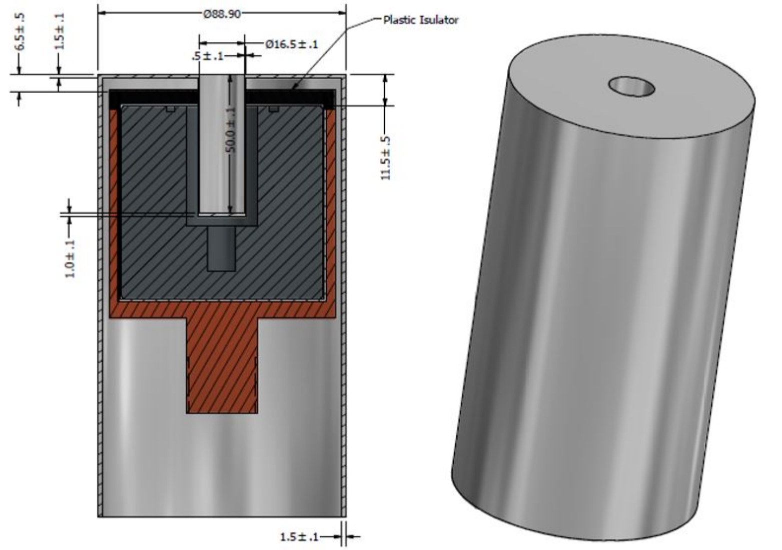
Nuclide Name	Id Confidence	Energy (keV)		Yield (%)	Activity (Bq /l)	Activity Uncertainty
K-40	0.950	1460.82*		10.55	6.430539E+01	3.713858E+00
I-125	0.911	4.08	@	14.70		
		27.30*		112.50	7.388196E+01	2.535730E+01
		31.06*		20.90	9.509974E+01	2.556538E+01
		31.76	@	4.54		
		35.49*		5.82	9.036437E+01	1.812737E+01

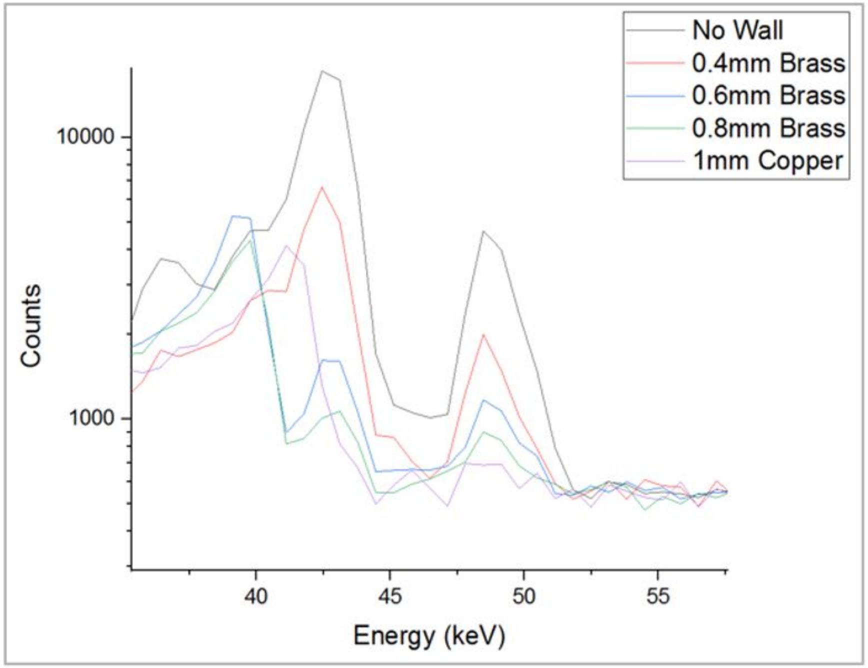
***** I N T E R F E R E N C E   C O R R E C T E D   R E P O R T *****



Well detector and WEFFTRAN

- WEFFTRAN is used for well detectors and provides corrections for self absorption in the sample, true coincidence summing (TCS) effects and efficiency transfer while achieving maximum flexibility with respect to sample composition and volume.
- TCS effects are particularly prominent for well detectors for what reason we decided to include a metal vial (in addition to a plastic vial) in order to reduce impact from low-energy X-rays (as recommended by Tim Vidmar).
- Tests were made of vials made of copper and brass with different wall thicknesses. A choice was made of using brass vials of 0.4 mm thickness which filters out nearly all photons below 40 keV while allowing a decent transmission (33%) of 47 keV photons. Copper is relatively soft and could not be machined below 1 mm thickness.
- Calibration measurements were made of multi-gamma solutions containing Ba-133, Cs-134, Cs-137, Eu-154) in vials of plastic and brass.
- Most routine analyses in the well detector cover ashed aerosol samples from air filter collectors and use plastic vials.

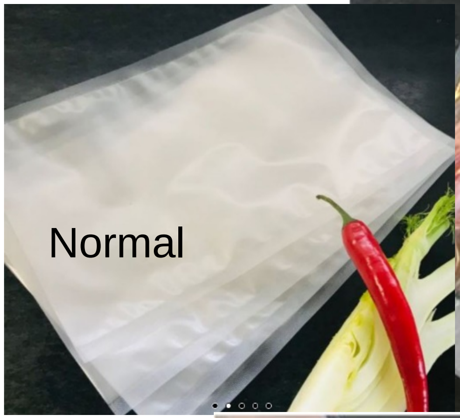




Eu-154 X-rays

Ra-226 analysis by gamma spectrometry

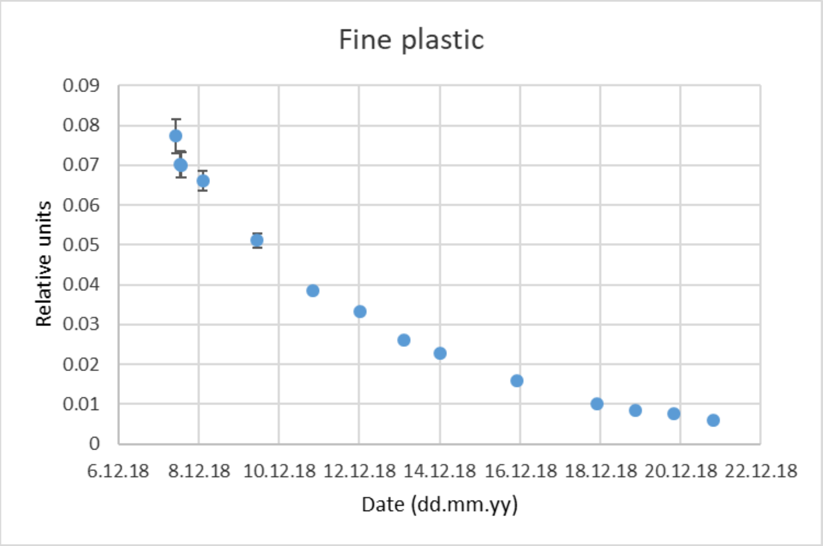
- Laboratory analysis of Ra-226 in environmental samples may be done by gamma spectrometry of the 186 keV gamma energy, which may interfere with U-235 having an intense gamma line of the same energy.
- Gamma analysis of Ra-226 in environmental samples may also be carried out from Pb-214 and Bi-214 after ingrowth when equilibrium has been established.
- Reliable results from the latter approach requires 1) that sample containers do not leak radon and 2) that the containers are completely filled with sample avoiding empty space where radon gas (and daughters) may accumulate resulting in an inhomogeneous distribution.
- Some years ago we consulted colleagues in Norway (IFE) and Finland (STUK) who told us that they use vacuum packing of sample containers and time (> 3 weeks) for ingrowth.
- We followed their example and acquired a vacuum packer and plastic bags of different qualities for testing their performance.



Testing of vacuum bags

- We first tested the bags by spiking water samples in 25 mL petri dishes with radon gas, vacuum packing the petri dishes inside the bags and gamma analyzing the samples over two weeks. The observed decays of Pb-214 and Bi-214 in the three samples were compared with the known decay of Rn-222. All samples showed decays in excess to that of Rn-222 corresponding to daily loss rates from 0.5% to 6%.
- Another test was made by using certified reference material (0.05% U) in 25 mL petri dishes, vacuum packing and gamma analyzing after one month. Observed concentrations of Pb-214 and Bi-214 were then compared with the certified U-238 concentration.
- Previous gamma analyses of the same reference material in non-vacuum packed plastic beakers and no time for build up had shown concentrations of Pb-214 and Bi-214 that were 15% lower than the reference value.
- The results of the vacuum-packed samples were all assigned a minimum standard uncertainty of 5%. The Pb-214 and Bi-214 concentrations for the three bags all overlapped the U-238 reference concentration based on En numbers (< 1).

$$E_n = \frac{A_{lab} - A_{ref}}{\sqrt{U_{lab}{}^2 + U_{ref}{}^2}}$$



Water sample vacuum packed in fine plastic analysed by gamma spectrometry on detector DET009 showing concentrations of short-lived radon daughters.

En numbers for the radionuclides tested for compatibility with uranium reference concentrations.

Isotope	Normal plastic	Fine plastic	Al-foil plastic
^{234}Th	-0.10	0.72	-0.30
^{234m}Pa	-0.10	-0.15	0.07
^{226}Ra	-0.01	-0.88	0.17
^{214}Pb	-0.20	-0.51	-0.35
^{214}Bi	-0.76	-0.71	-0.70
^{210}Pb	-0.49	-0.79	-0.65
^{235}U	0.81	1.10	0.07

Radon in natural gas

- Natural gas extracted from the North Sea is an important source of energy in Denmark. The gas is distributed and piped to consumers across the country. The gas contains small amounts of radon and for some years we have measured radon in the gas as well as Pb-210 and Po-210 in dust from the gas pipelines.
- We receive gas samples in a 1-L steel cylinder filled at 100 bar. The cylinder is placed in a lead shield of a Ge detector and measured 2-3 times overnight (Pb-214 and Bi-214)
- Calibration is carried out by filling a known amount of radon in the cylinder, placing it in the lead shield of the same Ge detector and performing 2-3 measurements.
- We have found radon concentrations in the natural gas in the range 30-100 Bq/m3.