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Measurement of natural gamma radiation in Belgium by means of high resolution in-situ spectrometry

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INTRODUCTION

The availability during the last decade of portable large intrinsic germanium detectors has greatly enhanced the application field of in-situ γ–spectrometry. This technique (described by Beck et al. (1), Miller et al. (2, 3) and in the ICRU report 53 (4)) was initially used for measurements of the fallout from atmospheric nuclear bomb testing.
It has been particularly useful in the follow up of the consequences of the Chernobyl accident in Europe. In the period 1995-1997, we have performed a series of in-situ γ–spectrometry measurements on 60 locations distributed across the Belgian territory. The first aim of this campaign was to make a survey of the ^{137}Cs contamination in Belgium (5,6), but careful analysis of the spectra also produced a nice set of data concerning the natural radioactivity of the ^{40}K, ^{238}U-series and ^{232}Th-series. Our results are compared with data obtained from an airborne survey using sodium-iodide crystals.

EXPERIMENTAL PROCEDURE

The in-situ measurements were performed with three different measuring chains, two from the Ghent University (RUG) and the other of the SCK•CEN Mol. During the first measuring campaign in 1995, the RUG detector is a 20.2 % p-type (energy resolution 1.7 keV) with a normal 30 liter dewar, coupled to on S2011 amplifier and a S20 multichannel analyzer. The SCK chain uses an n-type HPGe coaxial detector (resolution 1.83 keV and efficiency 10%) mounted on a small multi-attitude cryostat. Both spectrometers were calibrated independently and intercompared during simultaneous in-situ measurements at locations in Mol and Tihange. All results are in good agreement within a total experimental error of about 15%. In 1996 and 1997 a series of complementary measurements with a new larger detector (34% efficiency and 1.75 keV resolution with a 7.5 liter multi-attitude cryostat) and a new measuring chain with an integrated InSpector module (Canberra Ind.) were carried out.
The detectors are always placed 1 meter above ground level in the center of a large, undisturbed grassland. Figure 1 shows pictures of the old (1995, left) and new (1997, right) setup in field conditions.

Fig. 1 : Photographs during measurements with both RUG-detectors

A typical spectrum with the large detector in a region with average concentrations of both natural and man-made (^{137}Cs) isotopes is shown in fig. 2 (measuring time 3000s). The energies of the most prominent γ–lines from the decay of the uranium and thorium series and the potassium-line are indicated. In the activity

concentration calculations we assume a homogeneous distribution of the natural isotopes in the soil, corresponding to a relaxation parameter value of $\alpha = 0$ m^{-1}. For the calculations of the ^{137}Cs concentration we use a depth profile with relaxation parameter $\alpha = 20$ m^{-1} (relaxation length 5 cm, which is applicable to aged fallout (table 3.5 in (4)). The ^{137}Cs concentration of 2230 Bq/m^2 in Chimay is a typical value for our country (5,6).

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Fig. 2: Typical in-situ γ–spectrum, measured near Chimay in the south of Belgium

RESULTS

The results for the Chimay-site after analysis with CI Genie2K software are summarized in the following table:

^{40}K	1460.7				keV
	260				Bq/kg
^{238}U-series	**average**	242.0	295.2	351.9	keV
^{214}Pb	**26**	29.4	21.9	27.2	Bq/kg
		609.3	1120.3		
^{214}Bi	**25**	25.1	24.2		Bq/kg
^{232}Th-series	**average**	238.6			keV
^{212}Pb	**30**	30.1			Bq/kg
		338.3	911.2	969.0	keV
^{228}Ac	**27**	25.0	27.4	29.7	Bq/kg
		583.2			keV
^{208}Tl	**26**	26.0			Bq/kg

As one can see, 5 different lines from the U-series and 5 for the Th-series give an unmistakable indentification of the isotopes. The concentrations have errors in the order of 20% and there is a good agreement between the concentrations calculated from different lines and isotopes from both series.

The overall averages 25 Bq/kg for the ^{238}U-series and 28 Bq/kg for the ^{232}Th-series are a good indication for the situation in Belgium.

Contour and post maps for potassium (fig. 3), uranium (fig. 4) and thorium (fig. 5) were created from our database with the Kriging gridding method using SURFER for Windows.

The numbers on the axes are the Lambert coordinates, a coordinate system widely used in Belgium; the country is situated between 49.5 and 51.5 N and 2.5 and 5.5 E.

Fig. 3: Contour and post map for ^{40}K. The values are in Bq/kg

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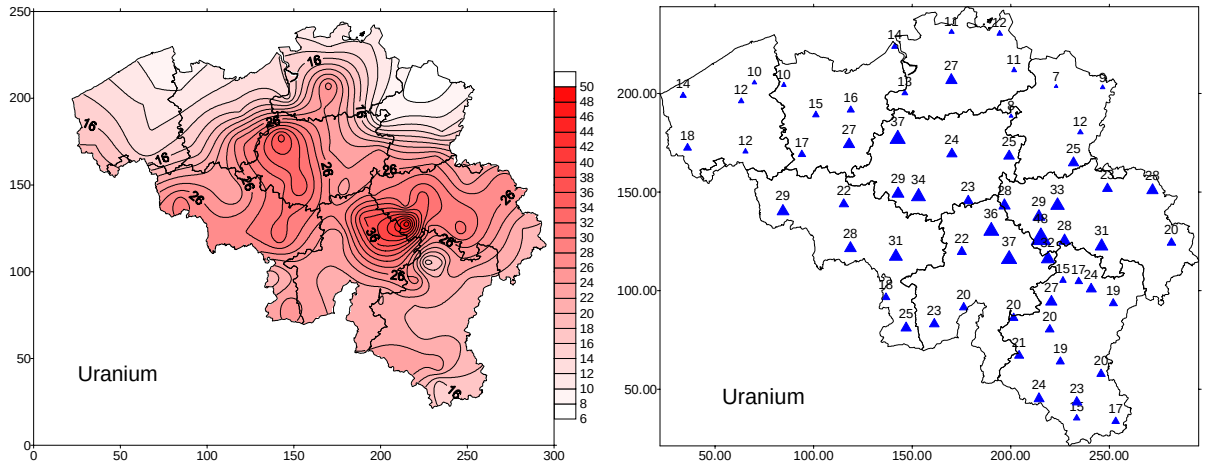

Fig. 4: Contour and post map for uranium. The values are in Bq/kg

Fig. 5: Contour and post map for thorium. The values are in Bq/kg

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DISCUSSION

As one can see on the maps, even a limited number of in-situ measuring points (60) gives a satisfactory overview of the isotope concentrations. The in-situ technique with a detector 1 meter above ground has the intrinsic advantage that a global value for a circle with 25 meter diameter around the detector position is obtained. As we can assume a relative uniform distribution of natural isotopes in the soil, even a limited number of 60 data points can provide sufficient information for map creation.
The reliability of the data is very good due to the use of high resolution gamma spectroscopy. The results are in agreement with geological data obtained from γ-spectrometry on soil samples. For example, in the Ghent region the data for ^{238}U, ^{232}Th and ^{40}K are respectively 14, 15 and 275 Bq/kg from the in-situ measurements and 16, 14 and 290 Bq/kg as an average value for 3 sets of soil samples .
The differences between the north-western part an the central and south-east part of the country can be explained by geological factors: in the Ardennes we find more rocky soil layers containing uranium and potassium.
We have also compared our results with the data of an airborne survey carried out in 1994 for the Ministry of Economic Affairs in Belgium (7). An airplane flying at 120 m above the ground level was equipped with a large scintillation detector and a 256-channel analyzer. Energy windows were used to separate the counts from ^{40}K (1.35-1.57 MeV), ^{238}U-series (1.63-1.89 MeV), and ^{232}Th-series (2.42-2.82 MeV). Corrections for cosmic and aircraft background were carried out.
The values on the airborne survey maps are in counts/s (cps), with approximate equivalence coefficients for the conversion to Bq/kg. The correspondence between our data and the airborne survey measurements is in general reasonable, taking into account the completely different methodology and detection systems involved. For example, in the Ghent region the airborne survey value of 100 cps for ^{40}K can be converted to 270 Bq/kg which value is very close to the 275 Bq/kg from the in-situ measurements.
Some discrepancies, especially in the uranium measurements, can probably be explained by weather effects on the gaseous radon in the ^{238}U decay scheme. The airborne survey is also sensitive to interferences with man-made sources of enhanced “natural” radioactivity, like the uranium containing stockpiles and waste storage grounds from some industries (phosphate and fertilizers factories, gypsum manufacturers, etc.).

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REFERENCES

1. Beck, H., De Campo J. and Gogolak C. , USDOE Report HASL-258 (1972)
2. Helfer, I. and Miller, K. , Health Physics, 55 No 1, 15-29 (1988)
3. Miller, K. And Shebell P. , EML - USDOE , EML-557 (1993)
4. ICRU report 53, ICRU, Bethesda, Maryland, USA (1994)
5. J.Uyttenhove, S. Pommé, B. Van Wayenberge, F. Hardeman, J. Buysse, J-P. Culot
Survey of the ^{137}Cs contamination in Belgium by in-situ gamma spectrometry, a decade after the Chernobyl accident
Health Physics, vol. 73, Nb. 4 (1997) 644-646
6. S. Pommé, J. Uyttenhove, B. Van Wayenberge, J-L. Genicot, J-P. Culot, F. Hardeman,
Radiocesium contamination in Belgium, J. Radioanal. Nucl. Chem. 235 (1998) 139-144
7. Airborne Geophysical survey, Ministry of Economic Affairs, Belgium (1994)