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Concentrations of radionuclides in soil and assessment of the environmental gamma dose

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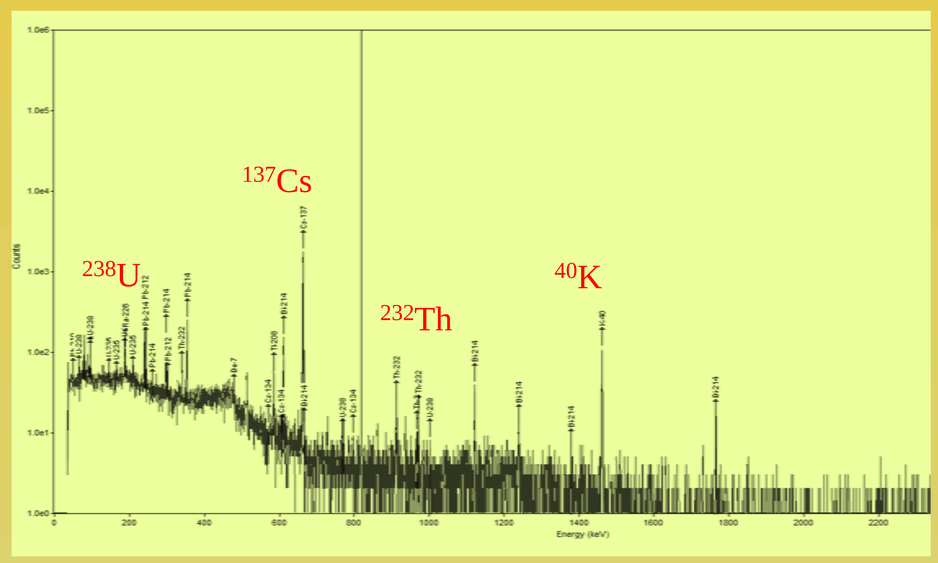
The main objective of this study was to identify and determine natural and artificial radionuclide activity concentrations in soil samples collected from seven locations in Serbia and asssessment of the enviromental gamma dose. Several different techniques for the assessment of environmental gamma dose are compared: high pressurized ionizing chambers at 2 locations and Geiger Mueller counters at 5 locations versus environmental thermo-luminiscent dosimeters and dose evaluation from the activity concentration of radionuclides in soil.



Introduction

To investigate and monitor environmental radiation at ground level, early warning environmental radiation system in Serbia is installed. The network has nine gamma dose rate detectors (figure 1). Seven of nine detectors are Geiger Müller tubes (AMES MFM 202 and MFM 203) and two are high pressurised ionizing chambers (HPIC RSS 112 Reuter Stokes).
Thermoluminescent detectors have been placed at the same stations, because this type of monitor allows one to measure long-term accumulation of dose.
One component of the radiation field at ground level is terrestrial radiation. The knowledge of radionuclide distribution in soil is important for dose assessment for the population. The natural radioactivity in soil comes mainly from the series radionuclides headed by ^{238}U, ^{232}Th, ^{235}U and from natural ^{40}K. Presence of artificial radionuclides, such as ^{137}Cs which can be found in soil samples, results from radioactive fallout after nuclear weapon testing and nuclear accidents.

Measured and calculated gamma dose rate in the outdoor air (nSV/h)

PIC RSS 112

MFM 203 AMES

Table 1. Radionuclide activity concentration in the soil in Serbia in 2008

	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)	^{232}Th (Bq/kg)	^{226}Ra (Bq/kg)	^{238}U (Bq/kg)	^{235}U (Bq/kg)
Belgrade	544 ± 22	36.5 ± 1.5	48.7 ± 3.4	42 ± 9	91 ± 23	2.2 ± 0.4
	577 ± 23	37.7 ± 1.5	53.7 ± 2.6	50 ± 10	117 ± 40	2.6 ± 0.6
Kladovo	482 ± 20	131 ± 4	37.4 ± 3.1	53 ± 12	96 ± 23	2.4 ± 0.7
	425 ± 18	107 ± 4	32.3 ± 2.9	41 ± 10	< 30	< 1.9
Niš	368 ± 17	27.2 ± 1.2	27.5 ± 2.9	52 ± 10	119 ± 15	3.2 ± 0.5
	406 ± 18	28.5 ± 1.3	29.6 ± 2.0	67 ± 11	146 ± 16	4.4 ± 0.6
Novi Sad	484 ± 20	17.0 ± 0.8	35.8 ± 3.0	43 ± 9	< 32	< 2.0
	514 ± 21	16.2 ± 0.9	45.1 ± 2.8	38 ± 10	88 ± 27	2.8 ± 0.8
Palić	351 ± 16	5.7 ± 0.5	31.2 ± 2.6	37 ± 8	74 ± 17	2.3 ± 0.8
	393 ± 17	7.0 ± 0.6	33.3 ± 2.9	38 ± 10	85 ± 18	2.0 ± 0.6
Zlatibor	162 ± 10	176 ± 6	9.8 ± 2.0	29 ± 9	28 ± 7	< 1.3
	188 ± 11	196 ± 6	13.2 ± 1.6	33 ± 11	< 26	< 1.5
Vranje	600 ± 23	31.4 ± 1.4	70.0 ± 4.1	54 ± 13	113 ± 45	3.2 ± 0.7
	544 ± 22	30.0 ± 1.3	63.4 ± 3.9	45 ± 94	85 ± 33	2.8 ± 0.5

Table 2. Radionuclide activity concentration in the soil in Serbia in 2009

	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)	^{232}Th (Bq/kg)	^{226}Ra (Bq/kg)	^{238}U (Bq/kg)	^{235}U (Bq/kg)
Belgrade	725 ± 28	9.6 ± 0.7	63.7 ± 4.0	50 ± 12	65 ± 25	2.5 ± 0.7
	685 ± 27	25.2 ± 1.2	57.8 ± 3.9	55 ± 10	47 ± 10	2.5 ± 0.6
Kladovo	624 ± 25	28.4 ± 1.1	38.6 ± 3.5	48 ± 10	53 ± 13	2.9 ± 0.3
	595 ± 24	28.9 ± 1.3	42.2 ± 2.1	42.0 ± 9.8	30 ± 10	< 1.9
Niš	517 ± 22	17.1 ± 0.9	29.6 ± 2.5	41.8 ± 9.6	< 28	< 1.9
	511 ±21	19.2 ± 1.0	29.8 ± 3.3	38.3 ± 9.7	39 ± 12	2.2 ± 0.6
Novi Sad	541± 23	15.8 ± 0.9	40.4 ± 3.2	39 ± 10	48 ± 19	1.8 ± 0.6
	572 ± 24	16.1 ± 0.9	42.4 ± 3.9	45 ± 10	49 ± 12	2.7 ± 0.6
Palić	364 ± 17	11.1 ± 0.7	23.5 ± 2.4	24.0 ± 6.7	31 ± 9	< 1.2
	400 ± 18	10.3 ± 0.7	23.6 ± 2.5	30.4 ± 8.7	40 ± 12	1.9 ± 0.5
Zlatibor	361 ± 17	161.4 ± 5.2	22.1 ± 3.0	31 ± 10	41 ± 12	1.7 ± 0.6
	396 ± 18	158.8 ± 5.1	22.6 ± 2.7	31 ± 10	39.8 ± 8.3	1.6 ± 0.6
Vranje	684 ± 27	41.3 ± 1.7	70.8 ± 4.4	66 ± 13	67 ± 23	3.0 ± 0.7
	661 ± 26	40.0 ± 1.7	68.9 ± 4.6	59 ± 12	65 ± 16	2.7 ± 0.7

Materials and methods

The HPIC RSS 112 is 8 liter spherical ionization chamber filled with ultra high purity argon to a pressure of 25 atm.

Monitors at six sites are equipped with gamma probes MFM 203 and one is equipped with MFM 202 made by the Slovenian company AMES d.o.o. and precipitation gauges.

A high sensitivity TLD system (Harshaw 6600), designed for the survey of the environmental radioactivity is based on the use of TL detectors with four crystals: two crystals $CaSO_4$ and two crystals LiF.

At the same locations soil samples were collected and gammaspectrometry measurements were made twice a year. Each sample was dried in an oven at 105°C-110°C to constant weight during 24-48 h. The dry soil was crushed and sieved (0.5 mm).

Natural and artificial radionuclides activity concentrations were measured using HP Ge spectrometer. The radionuclide activity of uranium and thorium series and ^{40}K, as well as the artificial radionuclide ^{137}Cs was determined. The activity concentrations of ^{232}Th and ^{238}U were calculated assuming secular equilibrium was established with their decay products.

Conclusion

Differences in response to background radiation come from characteristic of measurement site, but also from characteristics of different detector types. Data from TLD placed in the vicinity of gamma dose rate detectors confirm variations in response to background radiation as a consequence of differences in detector characteristics.

Measured gamma dose rates are higher than calculated from measured activity concentrations of natural radionuclides present in soil because the detectors measured also cosmic radiation in air besides the ground radiation.

The average HPIC dose rate values were in good agreement with the average two year LiF TLD values. The differences between results obtained by TLD and GM are systematic and indicate imperative recalibration of GM counters.