HPGE DETECTOR SHIELDING ADJUSTMENT

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INTRODUCTION

Low-level background shielding of HPGe detectors is used mainly for environmental samples with very low content of radionuclides. National Radiation Protection Institute (SÚRO) in Prague is equipped with 14 HPGe detectors with relative efficiency up to 150%. The detectors are placed in a room built from materials with low content of natural radionuclides and equipped with a double isolation of the floor against radon. Detectors themselves are placed in lead or steel shielding. Steel shielding with one of these detectors with relative efficiency of 100% was chosen to be rebuilt to achieve lower minimum detectable activity (MDA). Additional lead and copper shielding was built up inside the original steel shielding to reduce the volume of the inner space and filled with nitrogen by means of evaporating liquid nitrogen.

ADJUSTMENT OF THE SHIELDING OF HPGE DETECTOR

The original shielding was made of 20cm thick steel of 9000 kg total weight, inner volume around the detector was about 330 dm^3. The detector and the Dewar vessel are placed inside the shielding. During the upgrading a steel horizontal plate was placed into the existing shielding between the detector and the preamplifier. Additional lead and copper shielding were arranged on this plate. A door-equipped copper box was used as a further shield of the detector inside the original shielding. The weight of the additional shielding was almost 500kg and reduced the free volume around the detector to 30dm^3, which still allowed measurement of 3L volume Marinelli beakers. Output of gaseous nitrogen vaporizing from the Dewar vessel was attached to the copper box. Due to the supply of nitrogen a slight overpressure was expected in the copper box to reduce air input from outside of the shielding. Figure 1 shows a schematic representation of the adjusted additional passive shielding (side view).

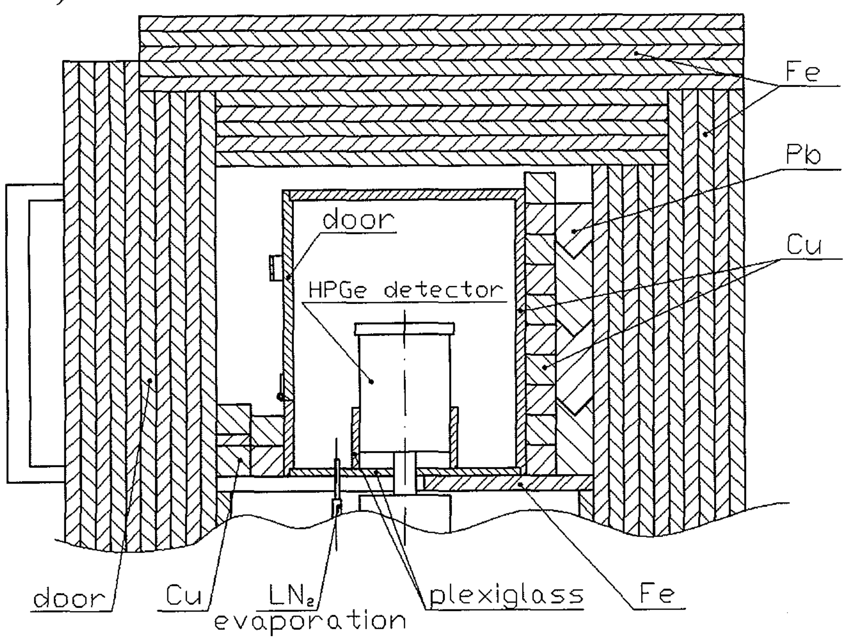

Figure 1. Schematic representation of the adjusted additional shielding – Side view

MEASUREMENTS AND RESULTS

In order to evaluate the effect of the additional shielding, net peak areas, count rates in different energy ranges, and MDA values for natural radionuclides and "Compton background" were compared in three arrangements: original shielding, additional shielding filled with evaporated N_2 (LN_2 evaporation) and additional shielding without N_2.
Spectra counted in the original shielding were recorded during 2006 and 2007. Ten measured spectra were used in calculations. Data from the additional shielding with LN_2 evaporation were collected at the beginning of 2008 (9 measurements) and data from the additional shielding without LN_2 evaporation have been collected since July 2008 up to September 2008 (6 measurements).
Effect of the new shielding is noticeable mainly in low-energy background range and in natural radionuclides peaks.

Table 1 presents net peak areas of naturally occurring radionuclides and ratio of these values after the adjustment and before. Net peak areas of ^{214}Pb and ^{214}Bi decreased from 6% up to 14% of original level after the adjustment. Without LN_2 evaporation the decrease is lower, only about 40% of original value. The influence of evaporation and consequential overpressure of nitrogen is significant. Decrease of ^{40}K net peak area is up to 70% and of ^{208}Tl up to 38% for measurements both with and without LN_2 evaporation

Table 1. Net peak areas of naturally occurring radionuclides and integral count rate results after the adjustment and before

	Net peak areas per 1000s					
	^{214}Pb 352 keV	^{214}Bi 609 keV	^{214}Bi 1120 keV	^{214}Bi 1764 keV	^{40}K 1461 keV	^{208}Tl 2614 keV
Original shielding - A	10.9 ± 3.7	9.3 ± 3.7	2.4 ± 0.9	2.1 ± 0.8	1.5 ± 0.2	2.6 ± 0.4
Shieldig with LN_2 evaporation - B	1.1 ± 0.5	1.2 ± 0.2	0.2 ± 0.1	0.3 ± 0.1	1.0 ± 0.2	1.0 ± 0.1
Shieldig without LN_2 evaporation -C	4.3 ± 1.8	3.8 ± 1.5	1.1 ± 0.3	1.1 ± 0.1	1.0 ± 0.2	1.0 ± 0.1
Ratio (B/A) [%]	10%	13%	6%	14%	71%	38%
Ratio (C/A) [%]	40%	41%	33%	43%	70%	37%
	Number of counts per 1000s					
Energy interval	10 - 101keV	10 - 320keV	101 - 320keV	10 - 2800keV	101 - 2800keV	320 - 2800keV
Original shielding - A	450 ± 20	1740 ± 70	1290 ± 50	2890 ± 120	2440 ± 100	1150 ± 50
Shieldig with LN_2 evaporation - B	340 ± 10	1300 ± 20	970 ± 10	2280 ± 20	1940 ± 20	980 ± 10
Shieldig without LN_2 evaporation - C	340 ± 1	1330 ± 5	990 ± 4	2330 ± 5	1990 ± 5	1010 ± 2
Ratio (B/A) [%]	75%	75%	75%	79%	80%	85%
Ratio (C/A) [%]	75%	76%	77%	81%	82%	87%

Integral count rate results are also given in Table 1. The count number decrease is the highest at the lowest energies. Number of count decreases to 75% of original value in energy interval 10-101 keV. With increasing energy the shielding influence is lessening. In energy interval 320-2800 keV the ratio is 85%. There are no significant differences between measurements with and without the LN2 evaporation.
MDA values were calculated for 250 000 s measurements time, 3 litres Marinelli beaker geometry, sample density $\rho = 1$ g/cm^3 and for gamma emission equal to 1 photon per decay. MDA values were calculated separately for Compton background (without naturally occurring peaks) and for selected naturally occurring radionuclides. The effect of the new shielding on MDA values for Compton background differs for different energy ranges. In energy range from 30keV up to 400keV the ratios of MDAs in additional shielding with evaporated N_2 to those in original shielding, range from 0.65 to 0.85. In the energy range from 400keV to 2MeV these ratios are 0.70 - 0.97. Without evaporated nitrogen the ratios are between 0.67 and 0.94 for energies up to 400keV, in the higher energy range they amount from 0.80 to 1. Above 2 MeV the MDA values are comparable with those in the original

shielding and differences between evaporation of N_2 and no evaporation are negligible. Gamma emission is considered equal to 1 photon per decay too.

CONCLUSION

The additional lead and copper shielding, consequent reduction of the inner volume and supply of evaporated nitrogen, caused a decrease of the background count and accordingly MDA values as well. The effect of nitrogen evaporation on the net areas of peaks belonging to radon daughters is significant.

The enhanced shielding adjustment has the biggest influence in low energy range, what can be seen in collected data. MDA values in energy range from 30keV to 400keV decreased to 0.65 - 0.85 of original value, in energy range from 400keV to 2MeV they fell to 0.70 - 0.97 of original value.