EVALUATION INFLUENCE OF RADON BACKGROUND TO LIMIT DETECTION

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Abstract

This paper describes a simple method to reduce radon background component to application environmental studies using gamma spectrometry. This method shows that, we can be minimized influence of radon daughter background such as ^{214}Pb, ^{214}Bi and ^{210}Pb (from ^{238}U), ^{212}Pb, ^{212}Bi and ^{208}Tl (from ^{232}Th). By the way, the detection limit of gamma spectrometry is discussed.

Keywords: gamma spectrometry, limit detection, background

1. Introduction

There are many efforts to the issues such as to look for the proper shielding materials better detector housing and so on. Techniques developed so far for rare event research, dark matter search in particle and nuclear physics research are well known. In this research we would like to investigate the most suitable and sensitive technique for fixing the background origin in the materials.

To improve the detection limits in low level activity measurements, the background has to be reduced as much as possible. The background spectrum of a germanium detector is due to a combination of different components such as environmental gamma radiation, radioactivity in the construction material of the detector, radio impurities in the shield, cosmic rays, radon gas. The first three contributions can be reduced drastically by means of a suitable passive shielding made of old or very low – activity lead and by a careful selection of materials surrounding the crystal. Cosmic ray component can be reduced by installing the germanium detector in an underground laboratory. However, building and operating an underground laboratory is expensive and inconvenient. Another possibility is to operate a gamma-ray spectrometer with an anticoincidence system i.e. a plastic scintillator surrounding the lead shield in anticoincidence with the germanium detector as active shielding. (G. Gilmore, 2008).

Radon isotopes, both radon, ^{222}Rn, and thoron, ^{220}Rn, are present in air as active gases emanating from traces of ^{238}U and ^{232}Th in building constructional materials and/or local soils and rock. Neither of these is particularly well endowed with gamma-ray emissions but their progeny are. These can be absorbed on dust particles and surfaces within the detector enclosure and give rise to characteristic peaks of ^{214}Pb, ^{214}Bi and ^{210}Pb, (from the ^{238}U series) and ^{212}Pb, ^{212}Bi and ^{208}Tl (in the ^{232}Th series) in the background. The difficulty with radon is that its concentration around the detector is likely to vary with time of day and season of the year, and with atmospheric pressure, wind speed, temperature, etc. A reliable and reproducible background from radon daughters is often difficult to achieve.

Using the vent gas from the liquid nitrogen Dewar would seem to be the most attractive option. At least one commercial low background shield incorporates purpose.

In this work, measurement and evaluation reduce radon daughter into background spectra with and without vent gas from the liquid nitrogen Dewar into the shielding.

2. Experimental

2.1. Detector

The experimental set-up is a low-level gamma spectrometer including an HPGe detector with conventional amplifying and coding systems. This is equipped with an active shielding consisting in plastic scintillators working in anti-coincidence mode. Table 1 is showed detail parameters of detector. Acquisitions with detector are driven using InterWinner software that is also used for spectra display and processing.

Table 1: Parameter of the HPGe detector

<table>
<tr><td colspan="2">Relative efficiency</td><td>51.6 %</td></tr>
<tr><td colspan="2">Active volume</td><td>220 cm^3</td></tr>
<tr><td colspan="2">Energy resolution (FWHM) at 122keV (^{57}Co)</td><td>0.99keV</td></tr>
<tr><td colspan="2">Energy resolution (FWHM) at 1332keV (^{60}Co)</td><td>2.05keV</td></tr>
<tr><td colspan="2">Peak-to-Compton ratio (^{60}Co)</td><td>62.4:1</td></tr>
<tr><td rowspan="9">Geometrical parameters of the detector</td><td>Window thickness</td><td>0.5 mm</td></tr>
<tr><td>Crystal-window distance</td><td>4.5 mm</td></tr>
<tr><td>Crystal dead layer thickness</td><td>0.3 μm</td></tr>
<tr><td>Crystal length</td><td>64 mm</td></tr>
<tr><td>Crystal diameter</td><td>66 mm</td></tr>
<tr><td>Crystal hole depth</td><td>51 mm</td></tr>
<tr><td>Crystal hole diameter</td><td>15 mm</td></tr>
<tr><td>Side cap thickness</td><td>0.5 mm</td></tr>
<tr><td>Side cap diameter (external)</td><td>82.5 mm</td></tr>
</table>

The detector is included in a cylindrical measurement chamber ($\phi = 80$ mm, H = 400 mm) made of 4 mm selected copper with a parallelepipedic shielding successively composed of 50 mm-thick very low activity lead (A < 10 Bq.kg^{-1}), 3 mm thick selected cadmium (A < 50 Bq.kg^{-1}) and 100 mm thick low activity lead (A < 50 Bq.kg^{-1}). The material composition of the bottom is the same except the thickness of low activity lead which is 150 mm. The measurement chamber is filled with nitrogen gas exiting from the cooling Dewar to remove radon from the chamber (figure 1). Finally, the whole system is installed in an underground laboratory isolated with 1.50 m concrete walls and 1 m underground. This room is also equipped with specific ventilation and air conditioning system with double dust filtering, thus insuring air regeneration 7 times per day. The active shielding is performed using 5 plastic scintillators with one of top and fourth for 4 surface and not bottom with dimension is 750x750x70 mm (L. Ferreux et al, 2009).

2.2. Standard solutions.

The efficiency curve was obtained using the so-called "SG50" volume geometry 50cm^3, container has the following characteristic: external diameter 40(1) mm, wall thickness 1.2 mm, bottom thickness 1.4 mm, the liquid is filled to high 4.56 mm. The initial efficiency curve was established in 2003, using nuclides such as ^{210}Pb, ^{241}Am, ^{109}Cd, ^{57}Co, ^{139}Ce, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{65}Zn, ^{22}Na, ^{60}Co, ^{40}K and ^{88}Y. A general efficiency curve (efficiency versus energy) was obtained by fitting a log log polynomial to experimental values obtained using the liquid standard sources.

3. Results and discussion

Figure 2a and 2b presented the measurement results with acquisition time 504000s when using shielding without and with nitrogen in to shielding respectively.

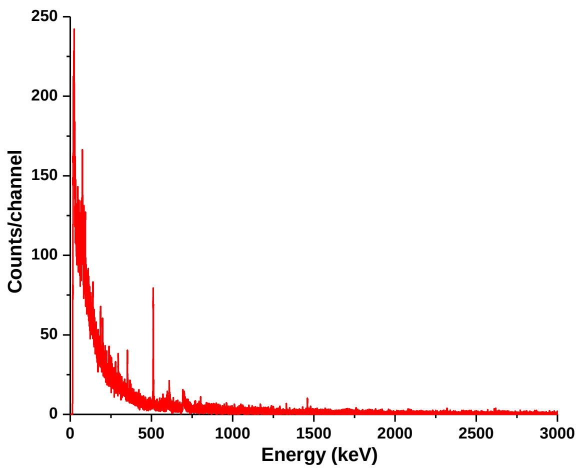

Figure 2a: The spectrum with nitrogen

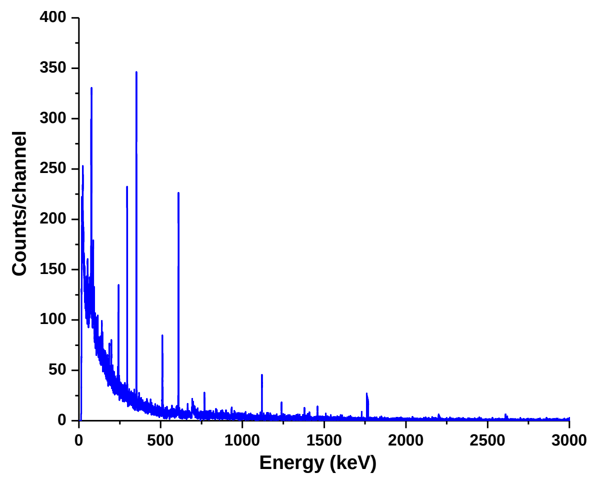

Figure 2b: The spectrum without nitrogen

Table 2: Comparison count rates peak (c.p.m) for with and without Nitrogen into shielding

Radionuclides	Energy (keV)	With Nitrogen (W) (c.p.m)	Without Nitrogen (Wo) (c.p.m)	Ratio Wo/W
^{210}Pb	46.5	0.022(2)	0.022(2)	1.0
^{226}Ra	186.2	0.026(2)	0.026(2)	1.0
^{212}Pb	238.6	0.022(2)	0.060(3)	2.7
^{214}Pb	295.2	0.019(2)	0.196(5)	10.1
^{214}Pb	351.9	0.022(2)	0.326(6)	15.0
^{214}Bi	609.3	0.019(2)	0.225(5)	11.6
^{214}Bi	1764.5	0.002(0)	0.040(2)	25.8
^{208}Tl	2614.5	0.006(1)	0.009(1)	1.4

0.022(2) = 0.022 ± 0.002

Regarding radon suppression the effect of its removal is shown in Table 2. Some reduction is observed in the gamma ray peaks of the ^{222}Rn progenies,^{214}Pb and ^{214}Bi those are by factors of 10.1 – 15.0 for ^{214}Pb and 11.6 – 25.8 for ^{214}Bi. Besides, ^{220}Rn daughter, the count rate in ^{212}Pb is reduced 2.7 and 1.4 for ^{208}Tl.

However, several applications of environmental radioactivity require not only low background but also lower limit of detection (L_D) for different samples. It has been obtained according to Gilmore (2008) using the equation:

$$L_D = 2.71 + 3.29\sqrt{B(1 + n/2m)} \quad (1)$$

Where B is the integral background in the region of interest (counts), n is the number of channels in the peak region of interest, m is the number of background channels on each side of the peak.

The minimum detectable activity (MDA) was calculated:

$$MDA = \frac{L_D}{\varepsilon . I_\gamma . t . V} \quad (2)$$

ε is the detection efficiency of the peak, Iγ is the gamma ray emission probability and t is the acquisition time(s) and V is the sample volume or mass. In Eq. (2), the confidence level is 95%.

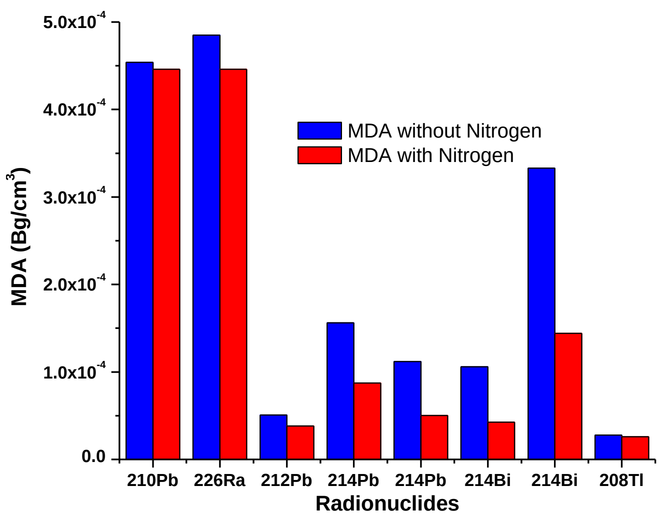

Figure 3: Comparison MDA values for SG50 geometry with and without nitrogen in sheilding.

On the other hand, the MDA is calculated for HPGe detector for a SG50 geometry as follows formula 2. The MDA is clearly improved (see Figs. 3) using radon suppression system for the ^{222}Rn progenies and ^{220}Rn daughter.

Because, ‘environmental’ origin soils, waters and such like are measured either to determine background levels of radiation or to assess the level of contamination as a consequence of human activity. The nuclides usually measured by gamma spectrometry are the cosmogenic nuclides: ^{40}K, ^{235}U, ^{238}U and ^{232}Th. In many cases, it will be necessary to make a peaked background correction in addition to the normal peak background continuum subtraction. All of those difficulties are then compounded by the fact that there are a large number of mutual spectral interferences between the many nuclides in the decay series of uranium and thorium.

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