EVALUATION OF LOW BACKGROUND GAMMA-SPECTROMETER WITH RADON SUPPRESSION USING MONTER CARLO CODE

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The Monte Carlo simulation has been performed to remove the contribution of ^{222}Rn to the low-background of gamma-ray spectra, which achieved from the HPGe gamma-ray spectrometry. Several configurations and conditions of flushing the central detector volume with nitrogen to actively remove the radon isotopes were simulated to evaluate the effect of Radon to the low-background spectra. The HPGe system at the NAA lab (KAERI, Republic of KOREA) will be setup based on the simulated results to measure environmental samples.

I. INTRODUCTION AND METHOD

I.A. Introduction

Low-background gamma-ray spectrometry has been developed for many years and widely applied in different fields such as fundamental physics researches and conventional sample investigations (Ref. 1). Recently, as detections of rare events such as neutrino interaction, dark matter, and neutrinoless double beta decay have accelerated and monitoring of environmental radioactivity has been highly focused on. Low-background HPGe gamma spectrometers are playing an increasingly important role in material selections for rare event experiments and measurements of environmental samples (Ref. 2, Ref. 3, and Ref. 4).

One of the main challenges of all ultra-low background germanium spectroscopy is the presence of radon isotopes in air. This is as a result of emanation from trace amounts of ^{238}U and ^{232}Th producing radon, ^{222}Rn, and thoron, ^{220}Rn, respectively. Although individually neither has significant gamma-ray emissions, their decay daughter does have as summarized in Table I. These gamma-lines contribute to the inherent background of the germanium detector, reducing the detector sensitivity. Radon levels inside and around the detector are also variable depending conditions such as temperature, pressure and time of the day, making consistently reproducible background measurements more difficult to achieve.

TABLE I. The daughter nuclides of radon isotopes, which emit gamma-rays and the respective energies.

Radon Isotope	Chain/Nuclide	Energy (keV)
^{222}Rn	$^{214}Pb \rightarrow ^{214}Bi$	295
	$^{214}Pb \rightarrow ^{214}Bi$	352
	$^{214}Bi \rightarrow ^{214}Po$	609
^{220}Rn	$^{212}Pb \rightarrow ^{212}Bi$	238

In order to reduce the effects of radon isotopes inside the spectrometry volume, there are three approaches, which can be taken as make the detector shielding as airtight as possible to prevent radon diffusion into the spectrometry volume, reduce the volume of air inside the spectrometry by filling it with sealed containers each filled with radon-free air such as nitrogen or helium, and flushing the spectrometry volume with nitrogen to actively remove the radon isotopes. Maintain constant overpressure by continuous flushing to suppress radon diffusion. In this study, the Monte Carlo simulation based on MCNP6 code (Ref. 5) has been applied to perform the third approach with several configurations of the HPGe spectrometry in the NAA lab (KAERI, Republic of KOREA).

I.B. Method

A series of measurements of radon activity levels and gamma background counting rates been performed to quantify and understand the evolution of these background components. To quantify the gamma background a set-up was prepared, consisting of a coaxial ORTEC HPGe detector (model number - GMX40-76) and the energy of events up to ~3

MeV was continuously registered. The simulated data were taken at the following distinct conditions: 1. After performing an N2 purge, injecting a high flux of N2 gas (1800 l/h) for about seven hours. In this way, the total N2 gas injected was twice the internal volume of the shielding; 2. With the injection of a low constant N2 gas flux (180 l/h), set after performing a second N2 purge equivalent to the first one; 3. After stopping the constant N2 gas flux in situation 2; 4. With the injection of a high constant N2 gas flux (900 l/h), also set after a new N2 purge equivalent to the previous ones.

The simulated background source can be modeled based on the advantaged features of MCNP6 that introduced a generic background source of neutrons and photons from a *background.dat* source file. The *background.dat* file consisting of generic terrestrial soil emission spectra (from K, U, Th, etc. decay) include not only air to ground transport effects but also ground reflection effects (Ref. 5).

The simulation background with and without nitrogen flushing are shown in Figure I. It is obvious that, after flushing with nitrogen, the background level dropped significantly due to the reduction of ^{222}Rn concentration in the measurement chamber and the integral count rate between 100~2700 keV was only 4% of that without nitrogen flushing.

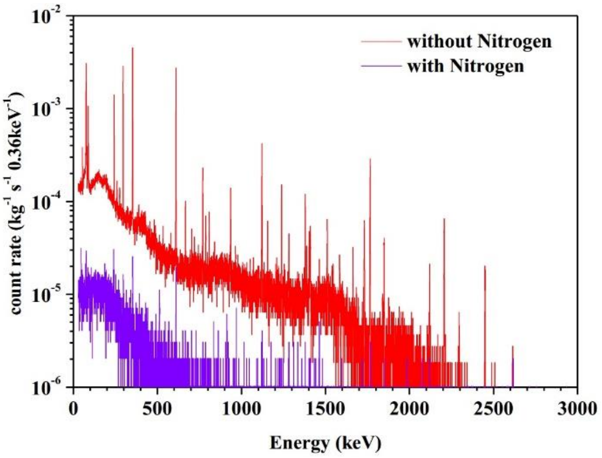

Fig. I. Background spectra of HPGe spectrometry with (blue) and without (red) N2 flushing by simulation.

II. CONCLUSIONS

^{222}Rn in the air around the detector contributes significantly to the remaining background and attention will be paid to the radon concentration, especially inside the sample chamber. The reduction of ^{222}Rn contributions was performed by using Monte Carlo simulation with some distinct conditions and showed significant improvements were possible by its removal.

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