Comparison of the Ground-Based Gamma-Ray Spectrometry in the Environment Using Different Halide Scintillators

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1. Introduction

The importance of environmental radiation survey has increased after the nuclear accident at the FDNPP (Fukushima Daiichi Nuclear Power Plants). Especially, the gamma-ray spectrometry of radioactive deposition is widely used to estimate the radioactivity in the ground as well as dose rate induced from the deposited nuclides [1-3]. In general, a portable HPGe detector can give a reliable results, providing that the in situ calibration is properly applied to the field measurement. However, there are still drawbacks about time and cost constrains, which mean the limited operation during cooling time and high expense including in situ calibration software.

Many kinds of scintillators have been developing and characterizing to meet the performance for gamma-ray spectrometry, that is, a light yield, proportionality, and energy resolution. These scintillation detector have merits for operating in the room temperature and mounting to diverse platforms, such as a tripod, backpack, carborne, and airborne unit. However, because of those insufficient energy resolution to efficiently identify the radioactive deposition, several spectrometers with a relatively good energy resolution have been attempted as an environmental radiation monitor.

In this study, four kinds of halide scintillators, NaI(Tl), $CeBr_3$, $LaBr_3$(Ce), and SrI_2(Eu), were used to perform the ground-based gamma-ray spectrometry for the purpose of estimating the dose rate and radioactivity for detected gamma nuclides in the environment. First, the performance was evaluated to check the peak shape by using a point source, when attached to a commercial signal processing unit. Finally, the ground-based gamma-ray spectrometry using four detectors was conducted to determine the dose rate and radioactivity for detected gamma nuclides. The results were successfully compared to results from a portable HPGe semiconductor detector.

2. Methods and Results

2.1 Halide scintillators

Four halide scintillators were selected to perform the ground-based gamma-ray spectrometry, including one of the longest-in-use NaI(Tl) scintillation material in a number of common applications. The heavy halide class scintillators of $CeBr_3$ and $LaBr_3$(Ce) were used to apply to the ground-based gamma-ray spectrometry. Finally, a SrI_2(Eu) scintillator was also selected in this study, due to the highest light yield.

As shown in Table 1, the heavy halide materials, $CeBr_3$ and $LaBr_3$(Ce), show high density and good light yield with respect to the counting efficiency of incident photons. Furthermore, a high throughput and excellent peak identification can be made from a very short decay time and good energy resolution. However, the intrinsic background radiation in the crystal itself make a severe effect to the gamma-ray spectrometry. A SrI_2(Eu) has the highest light yield and no intrinsic background radiation, but the long scintillation decay time can make a limitation to be applied to the high input count rate.

Table 1. Properties of four halide scintillators

Materials	Density (g/cm^3)	Light yield (#/MeV)	Decay time (ns)	Resolution at 662 keV (%)
NaI(Tl)	3.7	40,000	230	7.0
$CeBr_3$	5.2	60,000	17	3.9
$LaBr_3$(Ce)	5.3	65,000	20	2.6
SrI_2(Eu)	4.6	80,000	1000	3.4

- All data were referred from manufacturers' data sheet

2.2 Measured energy resolution

The performance of used halide scintillation detector was conducted by using a point source of ^{137}Cs and ^{60}Co, which was located 3 cm in front of a detector. The signal processing unit was then attached to the 12 pin connector of a photomultiplier tube in the detector package. This unit (SI Detection Co. Ltd., HAMPack MCA 527, KOR) includes a HV supplier, preamplifier, amplifier, and multi-channel analyzer (MCA). The measured energy spectra are shown in Fig. 1. In the case of a SrI_2(Eu), it requires a long charge collection time due to the slow decay time of the scintillation. Therefore, a long pulse shaping time of about 12 μs was then applied to the digital signal processing unit in the experiment. On the other hand, a 1 μs pulse shaping time was used in the other detectors. From the peak analysis induced from ^{137}Cs and ^{60}Co, the energy resolution was determined in the gamma-ray peaks of 662 and 1333 keV. The results are shown in Table 2. A good performance in the measured energy resolution was achieved, when compared with the data sheet of a manufacturer.

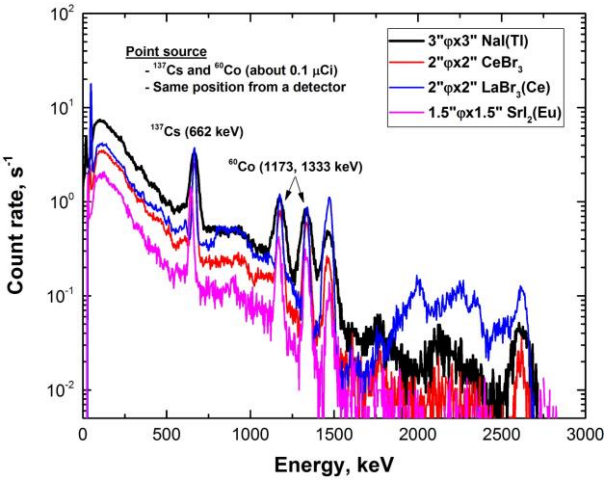

Fig. 1. The measured energy spectra using several halide scintillators.

Table 2. The measured energy resolution of four halide scintillators

Energy (keV)	Measured energy Resolution (%)			
	NaI(Tl)[a]	$LaBr_3$(Ce)[b]	$CeBr_3$[c]	SrI_2(Eu)[d]
662	6.65	2.63	3.73	3.24
1333	4.43	2.05	2.95	2.33

[a] 3”x3” NaI(Tl) detector (SCIONIX Inc.)
[b] 2”x2” $LaBr_3$(Ce) detector (Saint-Gobain)
[c] 2”x2” $CeBr_3$ detector (SCIONIX Inc.)
[d] 1.5”x1.5” SrI_2(Eu) detector (SCIONIX Inc.)

2.3 Ground-based gamma-ray spectrometry

After performance test in the laboratory, the ground-based gamma-ray spectrometry was conducted by location detectors at 1 m above the ground, as shown in Fig. 2. The dose rate spectroscopy [1-3] was then used to assess the radioactivity of natural radionuclides in the ground and dose rate at 1 m above the ground from one measured energy spectrum by the detector. Two information of ambient dose rate and dose rate of natural radionuclides were determined from the dose rate spectroscopy. A successful comparison was made between results of halide scintillation detectors and HPGe detector in the same site.

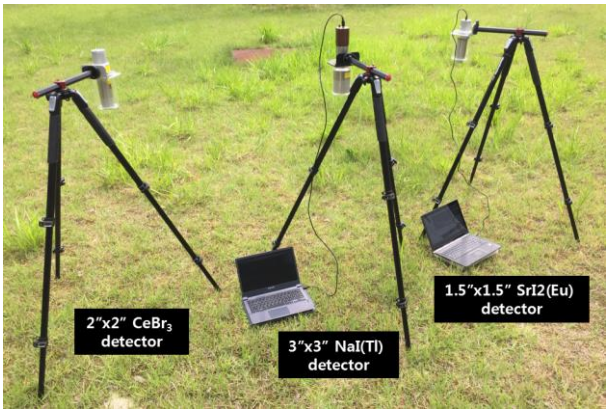

Fig. 2. The ground-based gamma-ray spectrometry.

3. Conclusions

Four kinds of halide scintillation detectors, that is, NaI(Tl), $CeBr_3$, $LaBr_3$(Ce), and SrI_2(Eu), were selected to make a performance test for the gamma-ray spectrometry. In the case of attaching the signal processing unit to a detector, the variation of energy resolution was evaluated in the measured energy spectra by using a point source. After the preparation of the dose rate spectroscopy of the halide scintillation detectors, a ground-based gamma-ray spectrometry was conducted to determine the ambient dose rate as well as dose rate by the nuclide and its radioactivity for detected gamma nuclides from only one measurement. The results were experimentally verified through an intercomparison of the in situ gamma-ray spectrometry results obtained using a portable HPGe semiconductor detector in the same site.

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