Portable $LaBr_3$ Detector Characterization and Radioactivity Calculation using the InterSpec and GADRAS-DRF

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1. Introduction

The analysis of nuclear and other radioactive materials in the management of radiological crime scenes is an essential element for identifying physical evidence [1]. The rapid analysis of nuclide and radioactivity on unidentified materials found at the site is important in responding to accidents. In this part, Mirion's In Situ Object Counting System (ISOCS) is famous and its functions are excellent. However, it takes a lot of time and cost to create the Detector Characterization Grid (DCG), which is the core process of detector characterization [2]. And the cost of the ISOCS software itself is may not be affordable. In contrast, there are InterSpec and GADRAS-DRF, which are freeware or limited freeware and allow to characterize a detector and approximately calculate the activity of source through a relatively simple process [3,4]. In this study, for a portable $LaBr_3$ detector that can measure various sources including nuclear material in the field, detector characterization was performed using the InterSpec and GADRAS-DRF, and the radioactivity was estimated and compared with the actual values.

2. Methods and Results

2.1 Detection of gamma sources

The portable detector used in the experiment is Mirion's SPIR-Ace $LaBr_3$ (Ce) model. The detector has a built-in $LaBr_3$ (Ce) scintillator of 1" by 1.34" and mainly measures gamma rays to perform functions such as spectroscopy and alarm through dose calculation [5]. Disk type check sources such as ^{241}Am, ^{60}Co, ^{137}Cs, ^{133}Ba, and ^{152}Eu were used as sources, and the activity is shown in Table I. Measurement data of ^{241}Am, ^{60}Co, ^{137}Cs, ^{133}Ba will be used for detector characterization, and those of ^{152}Eu will be used for testing the created detector response function.

The distance between the source and the detector was 25 cm. To minimize the scattering effect caused by objects such as a table, floor, and wall it was placed 100 cm above the floor using a steel frame, as shown in Fig. 1.

The energy spectrum was obtained by measuring 3600 sec for each source and the background.

Table I. Data of gamma source used in the experiment. The activities were corrected to the experiment date.

Source	Activity (uCi)	Main gamma peak (keV)
^{241}Am	50.754	68
^{133}Ba	8.129	81, 276, 303, 356, 384
^{60}Co	3.869	1173, 1332
^{137}Cs	9.177	661
^{152}Eu	19.274	122, 245, 344, 778, 867, 964, 1086, 1112, 1408

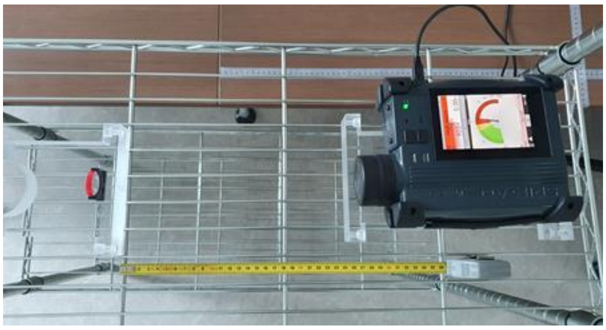

Fig. 1. $LaBr_3$ detector and gamma source on the steel frame.

2.2 Spectrum Analysis Tools

2.2.1 InterSpec

InterSpec is a free application developed for interactive analysis of spectral gamma radiation data by Sandia National Laboratories [3]. InterSpec uses a peak-based approach to help users identify what isotopes are present, determine their activities, and fit for shielding. The Gamma Detector Response and Analysis Software–Detector Response Function application (GADRAS-DRF) is also software developed by Sandia National Laboratories and computes the response of gamma-ray and neutron detectors to incoming radiation [4].

Using the two software, each detector response function was created with the spectrum obtained through the previous experiment. First, as shown in Fig. 2, the full energy peaks of the source were specified in the InterSpec. At this time, spectra of ^{241}Am, ^{60}Co, ^{137}Cs, ^{133}Ba sources were used, and energy calibration was performed.

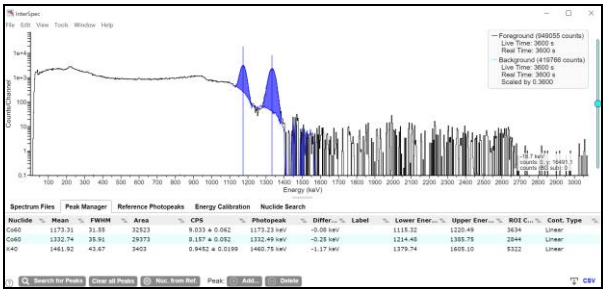

Fig. 2. The energy spectrum of ^{60}Co source and specified peaks in the InterSpec.

Using the Make Detector Response in Tools tab, appropriate peaks and parameters, and activity of sources are entered. Then, as shown in Fig. 3, the intrinsic efficiency and Full Width at Half Maximum (FWHM) are fitted and displayed. The background spectrum was subtracted from other energy spectra in the calculation process.

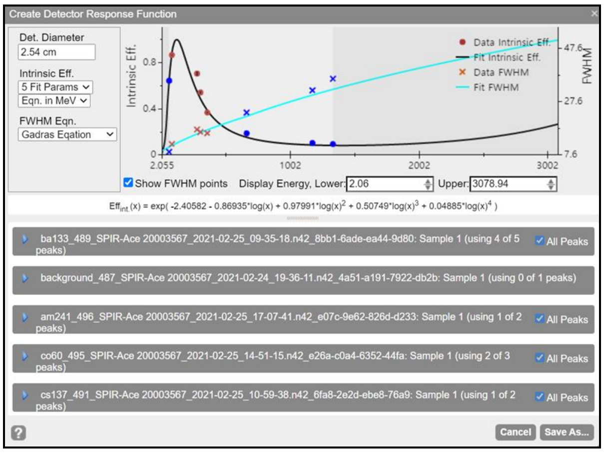

Fig. 3. Create Detector Response Function window in the InterSpec.

An activity of source was calculated using the Activity/Shielding Fit in Tools tab for the spectrum of ^{152}Eu source. After applying the response function of $LaBr_3$ detector previously made, when the peaks of ^{152}Eu are specified, the activity is calculated as shown in Fig. 4. The calculated activity of ^{152}Eu was 17.24 ± 0.033 uCi.

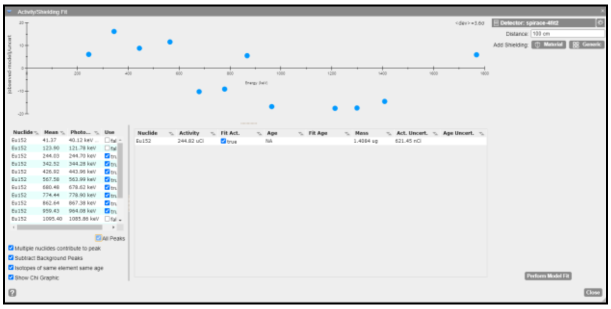

Fig. 4. Activity/Shielding Fit window and calculation of activity in the InterSpec.

2.2.2 GADRAS-DRF

In the GADRAS-DRF, when creating a detector response function, parameters of the detector such as length of setback, dead layer, and detector shape factor are able to be specified in more detail than the InterSpec. Unlike InterSpec, the calculation is used by applying values of these parameters to pre-calculated and embedded detector efficiency and FWHM values, rather than creating the response function from the energy spectra. The detector response function was created by inputting various geometry parameters and types of detectors such as $LaBr_3$, NaI, and HPGe. And energy calibration was performed through spectra of ^{241}Am, ^{60}Co, ^{137}Cs, ^{133}Ba, and background.

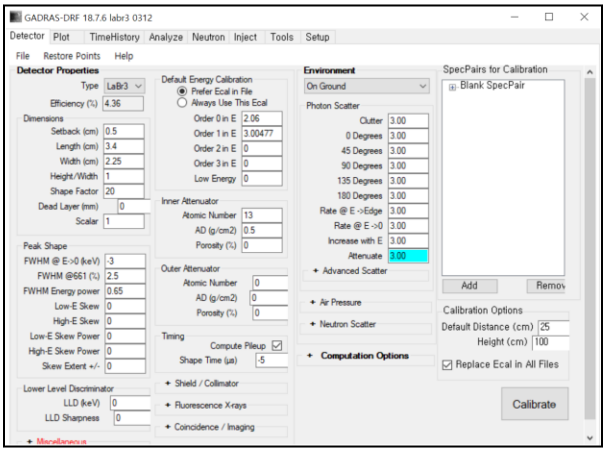

Fig. 5. Detector response function parameters for $LaBr_3$ in the GADRAS-DRF.

When the location of the source and the additional shield are specified in the Analyze tab, and the type of source is also specified, activity calculation is performed for the corresponding type of sources. In the calculation process, the background spectrum was subtracted from other spectra of check sources. The radioactivity of ^{152}Eu was calculated and found to be 18.23 ± 0.05 uCi.

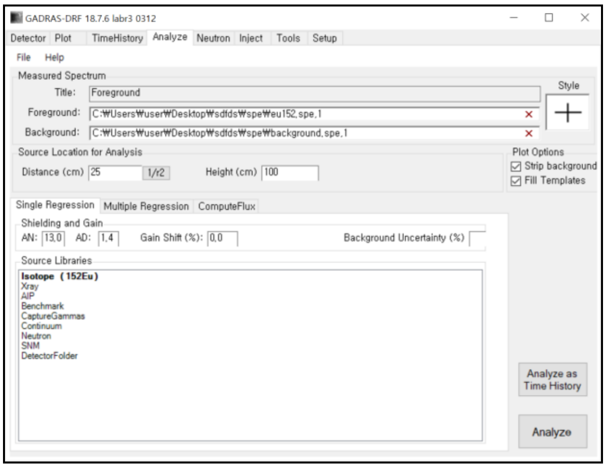

Fig. 6. Analyze tab in the GADRAS-DRF.

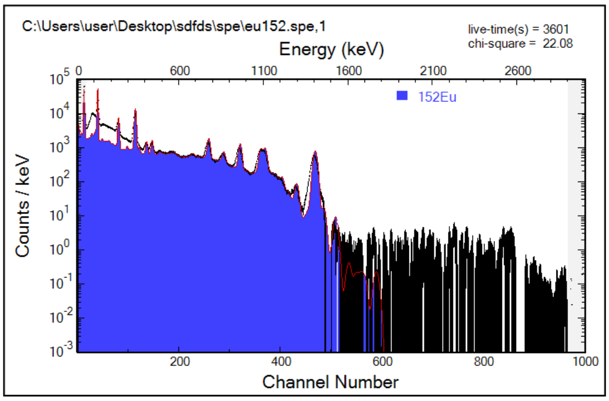

Fig. 7. Energy spectrum of ^{152}Eu from the experiment and calculation from GADRAS-DRF.

3. Conclusions

The InterSpec and GADRS-DRF are software that makes it simple to perform the detector characterization using different methods. The calculated values of activity of ^{152}Eu were 17.24 uCi and 18.23 uCi, respectively. The relative errors for the corrected activity of 19.274 uCi were 11.8% and 5.73%, respectively. The activity calculated using GADRAS-DRF was more accurate. It is determined to occur because the geometry parameters in GADRAS-DRF are set in more detail than in InterSpec.

The results of this study will be useful to figure out the advantages and disadvantages of each tool. In this study, bare isotope was the target of analysis using tools. However, it will be used as basic information for analysis of nuclear material such as U_3O_8 and UO_2 pellets, in the follow-up study. In the future, a technology optimized for preliminary characterization of unidentified nuclear materials using a portable gamma detector will be developed to maintain safety from nuclear accidents.

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REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Crime Scene Management, IAEA Nuclear Security Series No. 22-G, IAEA, Vienna, 2014.
[2] David Sullivan, Meriden, Henrik Jaderstrom, ISOCS/LabSOCS Detector Characterization Report, Canberra Industries, Inc., 2016.
[3] William Jonson, Quick Intro InterSpec gamma spectral analysis software, https://github.com/sandialabs/InterSpec, 2019.
[4] Steve M. Horne, Greg G. Thoreson, Lisa A. Theisen, Dean J. Mitchell, Lee Harding, and Wendy A. Amai, GADRAS-DRF 18.6 User's Manual, Sandia National Laboratories, 2016.
[5] SPIR-Ace Datasheet, https://www.mirion.com/products/spir-ace-radio-isotope-identification-device-riid, 2020.