Feasibility Study on Simulation-Based Efficiency Calibration for Environmental Gamma Spectrometry

Hyemi Cha,[1, a]* Jaehyeon Seo,[1, a] Younghak Kim,[1] Chang-jong Kim, [1] Jong-myoung Lim,[1] and Mee Jang [1]

[1]Korea Atomic Energy research Institute, Daejeon, Republic of Korea

** e-mail: hmcha@kaeri.re.kr corresponding/presenting author*

[a] These authors contributed equally to this work.

High-purity germanium (HPGe) gamma spectrometers are widely utilized for environmental radiation monitoring due to their superior energy resolution and efficiency. In current operational practice, efficiency calibration of HPGe gamma spectrometers is performed twice a year using certified gamma standard sources to maintain the accuracy of the measurements. However, this process requires substantial costs, manpower, operational downtime, and waste disposal procedures.

In our laboratory, long-term calibration data collected over the past nine years (2016-2024) indicate that the detection efficiency performance of gamma spectrometers has been consistently maintained at a stable level. Moreover, the intrinsic performance of HPGe detectors should not change dynamically once certified, suggesting a growing need for alternative methods that can reduce the reliance on frequent physical calibrations.

In this study, we aim to evaluate the feasibility of using simulation-based efficiency values calculated by tRAYcy, a Monte Carlo-based modeling tool developed by ORTEC for simulating the interaction of gamma radiation with matter. Experimental efficiency data were accumulated over the past nine years in our laboratory by measuring an HPGe spectrometer (GEM30P4-83, ORTEC) using a mixed gamma standard source containing nine radionuclides. Based on this detector, we constructed a corresponding model using tRAYcy, and efficiency values were calculated. As shown in Figure 1, the experimental efficiencies (blue) represent the averaged values from our measurements with a 1-liter Marinelli beaker geometry, while the tRAYcy-calculated efficiencies (red) show good agreement, with relative errors indicated at each energy point, remaining within 5%. Both efficiency curves were fitted using fifth-degree polynomials.

Future work will focus on refining our detector modeling in tRAYcy by incorporating additional factors such as time coincidence correction (TCC) and improving the detailed structure modeling. In addition, we plan to extend the approach to other HPGe spectrometers currently operated in our laboratory. Through these efforts, we seek to assess whether simulation-driven calibration could serve as a practical and reliable alternative to efficiency calibration procedures for gamma spectrometers used in environmental radiation monitoring.

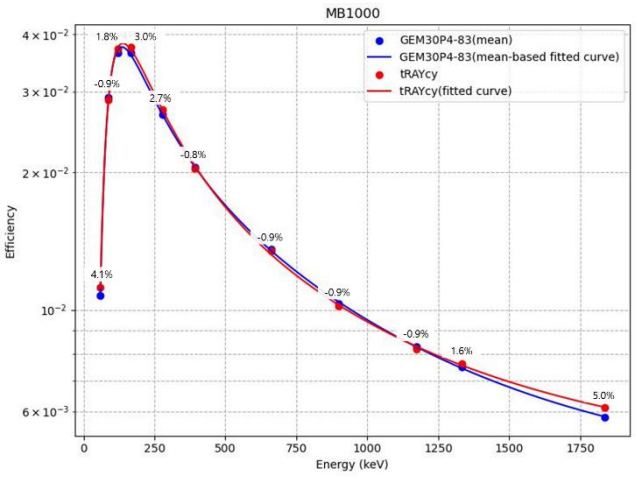

Figure 1. Comparison of experimental efficiency curves (blue) and simulation-based efficiency curves (red) for an HPGe gamma spectrometer.