Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 30-31, 2025

Development of real-time dose rate estimation method for pHGI leveraging the Radiation Equipment Fab. Center

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***Keywords :** Radiation Equipment Fab., dose rate estimation, CZT, Compton camera

1. Introduction

The Radiation Equipment Fab. Center at the Korea Atomic Energy Research Institute (KAERI) is conducting a key facility operation project to vitalize R&D in radiation technology. The Fab. Center supports various collaborative research projects by providing its infrastructure for developing core technologies, such as semiconductor sensors and radiation generators, to industry, academia, and research institutes. This study is one of the research outcomes leveraging the facilities and infrastructure of the Fab. Center, focusing on the development of core technology for the prototype hand-held-type gamma imager (pHGI) [1] applicable in security-sensitive environments such as customs sites. To overcome the limitations of conventional survey meters, which are restricted to dose rate measurements, we have developed a multi-functional system capable of radiation imaging, isotope identification, and dose-rate estimation. This paper presents the implementation and performance evaluation of a real-time dose rate estimation algorithm, a key function of the pHGI.

2. Methods and Results

2.1 Real-time dose rate estimation method

To estimate the real-time ambient dose rate, an algorithm was implemented that combines an experimentally measured energy spectrum with a detector response matrix derived from Monte Carlo simulations. The response matrix was generated using the Geant4 toolkit (version 10.04). The detailed geometry of the pHGI was modeled, and to eliminate the influence of the incident direction of gamma rays, a pencil beam source with an area identical to the detector's surface was modeled [2]. A total of 300 simulation cases were performed for gamma-ray sources with energies ranging from 10 keV to 3,000 keV in 10 keV increments. The resulting energy spectra from each simulation were organized into a 2D matrix, mapping the source energy to the measured counts. Subsequently, the air kerma was calculated using the experimentally acquired spectrum and the response matrix. The final ambient dose rate was determined by converting the air kerma to the ambient dose equivalent, H*(10), using the conversion coefficients from ICRP Publication 74 [3-5].

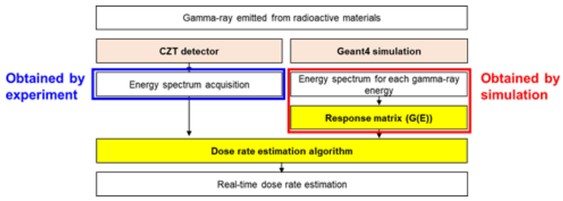

Fig. 1. Flowchart of the dose rate estimation method.

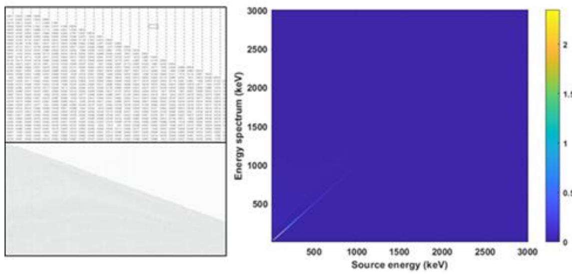

Fig. 2. Mapped detector response matrix.

2.2 Performance evaluation

The performance of the developed dose rate estimation algorithm was verified through comparison experiments with a calibrated gamma survey meter (RADEYE G-10, Thermo Fisher Scientific). The experiments were conducted in a specialized laboratory at the Radiation Equipment Fab. Center, located within the Advanced Radiation Technology Institute of KAERI. Under background radiation conditions, the pHGI measured a dose rate of 0.21 μSv/hr, showing a low error of 8.7% compared to the survey meter's reading of 0.23 μSv/hr. In a subsequent experiment, a ^{137}Cs (81 μCi) check source was placed 50 cm from the front center of the detector, and measurements were taken for 1 minute. The average dose rate from 10 repeated measurements was 1.06 ± 0.02 μSv/hr. This result demonstrated high accuracy with an error of 6.1% compared to the survey meter's measurement of 1.00 μSv/hr under the same conditions.

Fig. 3. Performance evaluation results for dose rate estimation.

3. Conclusions

This study experimentally demonstrated that the pHGI, developed by leveraging the infrastructure of the Radiation Equipment Fab. Center, can accurately estimate dose rates under various conditions with an error of less than 10%. This technology is expected to become a core component for enhancing both the efficiency of radiation inspection tasks and the safety of workers in security screening environments, such as customs inspections.

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