Fabrication and Performance Test of Scintillator Free-replaceable Type Detector for Comparison of Inorganic Scintillator Performance

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1. Introduction

In order to restore the site environment before and after the decommissioning of nuclear facilities, it is necessary to measure the radioactive contamination of the groundwater. On-site gamma monitoring technology for groundwater is being developed. A detector with good performance should be used to monitor gamma in real time. In this study, a scintillator free-replaceable type detector was fabricated to select a detector to be used for gamma monitoring. In order to confirm the possibility of utilizing the fabricated detector, the performance was evaluated through an experiment using a NaI(Tl) scintillator.

2. Materials and methods

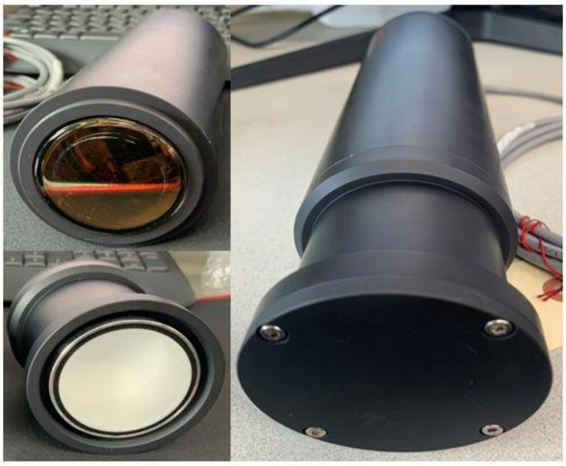

Fig. 1. Left: separated view of the detector. Right: combined view of the detector.

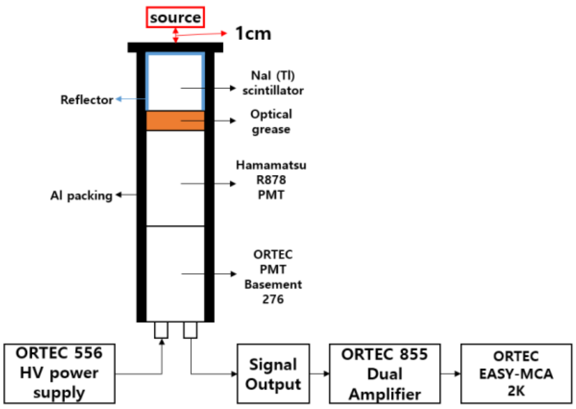

Fig. 2. Schematic diagram of the experimental setup and detection system.

Fig. 1 shows the fabricated scintillator free-replaceable type detector and Fig. 2 shows a schematic diagram of the experimental setup and detection system. The scintillator was used a 2 × 2 inch cylindrical NaI(Tl) scintillator which was covered with a reflector to transmit light generated by interaction with incident radiation to the photomultiplier tube (PMT). The scintillator was aluminum-packed to block external shocks such as hygroscopicity and external light. The lower part of the scintillator and the upper part of the PMT were made in a bolt-nut shape for easy replacement. PMT (Hamamatsu R878) was used to amplify the amount of photons emitted from the scintillator. A PMT basement (ORTEC 276) was used to convert the amplified photons into electric signals, and a voltage of 0.55 kV was applied using a high-voltage power supply (ORTEC 556) to operate PMT. The output signal was amplified using a dual amplifier (ORTEC 855), and an energy spectrum was obtained using a multi-channel analyzer (ORTEC EASY-MCA 2K).

For the performance test of the fabricated detector, calibrated gamma sources of ^{60}Co (12.9 kBq, Spectrum Techniques), ^{133}Ba (24.5 kBq, Spectrum Techniques) and ^{137}Cs (159.3 kBq, Spectrum Techniques) were used. The gamma sources were placed 1 cm in front of the detector, and energy spectrum was obtained by measuring for 30 minutes for each source.

3. Results and discussion

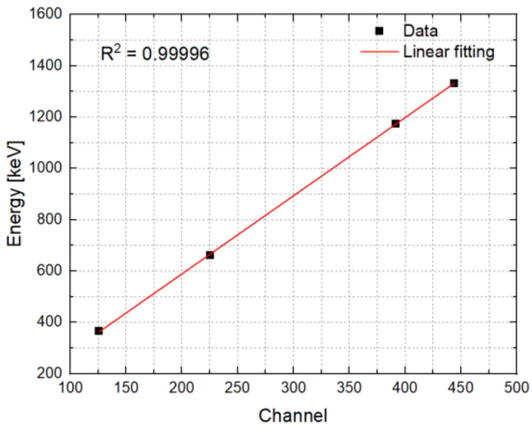

Fig. 3. Energy calibration of NaI(Tl) detector.

Four peaks (1.170 and 1.330 MeV of ^{60}Co, 0.356 MeV of ^{133}Ba and 0.662 MeV of ^{137}Cs) were identified in the obtained energy spectrum, and Gaussian fitting was performed for each peak. Energy calibration was performed based on the fitting result, and energy resolution and full energy peak efficiency (FEPE) were derived. Fig. 3 shows the result of energy calibration and linear fitting performed for 4 points. The R^2 value was 0.99996, which fits well linearly.

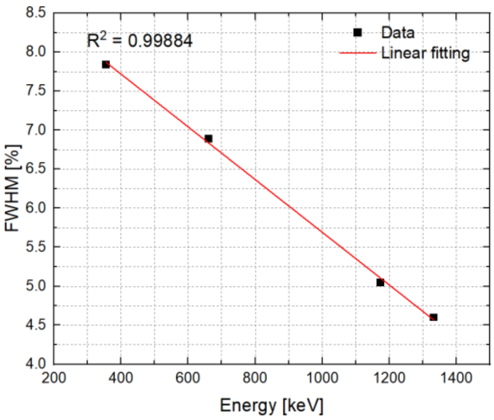

Fig. 4. Energy resolution of NaI(Tl) detector.

Fig. 4 shows energy resolution of NaI(Tl) detector. Y-axis of Fig. 4 is full width at half maximum (FWHM) of each percentage. The energy resolution at 662 keV was 6.8%, and it was similar to 7.0% shown in paper of R. Casanovas et al [1].

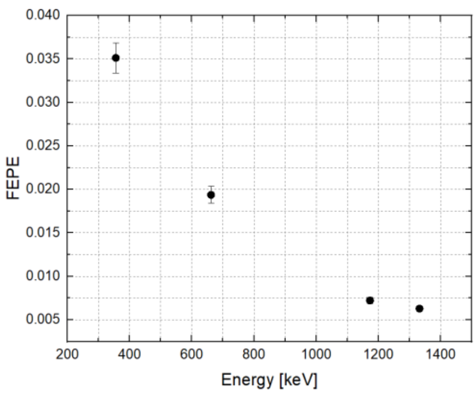

Fig. 5. FEPE of NaI(Tl) detector.

Fig. 5 shows absolute full energy peak efficiency (FEPE) of NaI(Tl) detector. FEPE at 356, 662, 1130, 1170 keV were 0.035, 0.019, 0.0072, 0.0063, respectively. And the detection efficiency formed a typical exponential decay function [2].

4. Conclusion

In this study, a scintillator free-replaceable type detector was fabricated to select suitable inorganic scintillator for gamma monitoring. The detector was fabricated easy to replace various scintillators to facilitate comparison and evaluation. In order to confirm that the fabricated detector works well, the experiments and performance evaluation were performed by using a NaI(Tl) scintillator. The energy spectrum was successfully acquired in the experiments. At 662 keV, energy resolution was 6.8% and FEPE was 0.019. It is expected that it will be utilized in the performance comparison experiments using other inorganic scintillators in the future study.

Acknowledgement

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[2] H. El-Gamal et al., Detection efficiency of NaI(Tl) detector based on the fabricated calibration of HPGe detector, Journal of Radiation Research and Applied Sciences, 2019.