Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2023

Development of the analysis software for aerial radiation monitoring

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***Keywords :** CZT sensor, Multi-channel radiation detector, Software, Radionuclide analysis, Aerial radiation

1. Introduction

To ensure a rapid emergency response in the event of nuclear accidents in neighboring countries, it is essential to measure the radionuclide information of radioactive plumes in the air [1]. Particularly, real-time assessments through field measurements are crucial in the initial stages for estimating emission rates and establishing response strategies.

Measuring the behavior of radioactive plumes enables the monitoring of radioactive contamination around nuclear facilities. For these measurements, radiation detectors need to be deployed in the atmosphere. For this purpose, a radiation monitoring system based on unmanned aerial vehicles (UAVs) can be utilized [2] and research is actively being conducted in the development of detection devices and software [3].

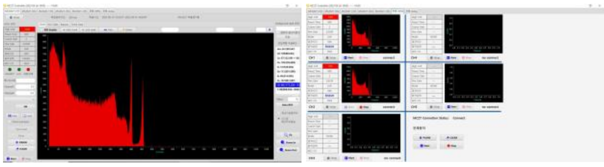
One widely used method for monitoring radioactive plumes involves identifying radioactive nuclides through gamma-ray spectrum analysis. In our previous studies, we designed a CZT-based multi-channel radiation detector capable of identifying the behavior and directionality of radioactive plumes. To control the multi-channel CZT sensors and monitor signals acquired from the sensors, it is necessary to develop the private software.

In this study, we developed software that interfaces with the multi-channel radiation detector and evaluated its performance. The software was developed using JavaScript, and its main functions include controlling the measurement of the detector and monitoring real-time data received from the detector. To verify the performance of the software, a comparison was made between the measurement results obtained from the developed software and those from the commercial software.

2. Methods and Results

2.1 Major functions of the software

The primary functions of the software can be categorized into multi-channel radiation detector control and measurement data analysis. Detector control involves supplying power to each CZT sensor, fine-tuning measurement signals, and issuing commands to start or stop measurements. The main feature of detector control is the capability to control single-channel CZTs individually or multi-channel CZT sensors concurrently, improving convenience.



(a) (b)

Fig. 1. Software measurement screen: (a) single-channel CZT sensor for detail analysis, (b) multi-channel CZT sensors for simultaneous monitoring.

Measurement data analysis displays the real-time energy spectrum measured by each CZT sensor on the screen. For major nuclides that may be emitted during accidents, Regions of Interest (ROI) are pre-defined. When selecting the set nuclide on the measurement data analysis screen, the ROI for that nuclide is automatically displayed. If peaks occur within the ROI, the software automatically generates Gaussian distributions for those peaks and calculates the Full Width at Half Maximum (FWHM) and the Full Width at Tenth Maximum (FWTM). Similar to detector control, it is possible to perform detailed analysis of data from a single CZT sensor or simultaneously monitor data from multi-channel CZT sensors, as shown in Fig. 1. The differentiated functions of the software are listed in Table I.

Table I: Key and differentiated function of the software

Categorization	Detail function
Multi-channel radiation detector control	- Multi-channel CZT sensors individual or concurrent control · High voltage supply · Measurement time setting · Measurement start/stop command - "Gain" fine tuning
Measurement data analysis	- Acquisition of gamma spectra measured by CZT sensors - Real-time measurement data monitoring - Energy calibration - Gaussian distribution generation - FWHM, FWTM calculation - Simultaneous monitoring for all measurement data in one screen

2.2 Gaussian distribution generation and calculation

FWHM is a method used to calculate the width of a nuclide peak in a measured spectrum, playing a crucial role in ensuring the accuracy of data analysis. To calculate the FWHM, it is necessary to refine the shape of the peak, for which Gaussian distribution or smoothing techniques are commonly employed. The Gaussian distribution provides a more accurate modeling approach, while smoothing techniques are primarily used for confirming data trends, noise reduction, and producing smoother representations.

For the calculation of a nuclide-specific dose rate, it is essential to accurately identify peaks and distinguish them from background radiation. This capability becomes particularly important in the low-energy range and in environments with varying radiation levels. Therefore, we have implemented the Gaussian distribution to improve the accuracy of the software, and applied a formula that automatically transforms the measured spectra peaks into the most suitable Gaussian distribution form.

2.3 Performance Test

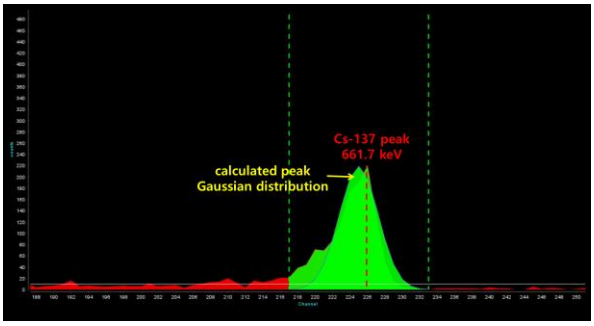


Fig. 2. Measured gamma spectrum and calculated peak Gaussian distribution for Cs-137 radiation source.

Table II: Comparison of the analysis data using Cs-137 radiation source

Peak Energy	**Data**	**Our software**	**Commercial software**
661.7 keV	Integral	1422.92	1423.00
	ROI Area	1093.00	1189.00
	FWHM	4.78	4.76
	FWTM	7.88	8.47

To verify that key functions of the software worked properly, a performance evaluation was conducted using a single-channel CZT sensor. A Cs-137 radiation source was measured for 1000 seconds to confirm the correct setting of ROI for the nuclide, the generation of a Gaussian distribution, and the accurate calculation of essential peak information.

The results are shown in Fig. 2 and Table II. Figure 2 shows the energy spectrum obtained from the measurement. As shown in Fig. 2, a peak occurred around 661.7 keV, and it can be observed that the ROI setting and generation of the Gaussian distribution were successful.

The same measurement data was entered into a commercial software using a smoothing technique, and the Integral, the ROI Area, the FWHM, and the FWTM were calculated and compared. Table II presents the results of the measurement data comparison. The Integral represents the sum of all count values within the ROI. For our software, the ROI Area represents the total count values within the area after excluding background radiation and applying Gaussian distribution, while commercial software considers it as the total count values after background radiation exclusion and the application of smoothing techniques. Despite setting the ROI identically, differences in the ROI Area, FWHM, and FWTM values were observed due to differences in calculation methods. While the FWHM values were similar at 4.78 and 4.76, the FWTM values have a noticeable difference at 7.88 and 8.47, respectively. Due to the difference between the two calculation methods, it is challenging to conclude which method is better. Depending on the measurement environment and the shape of the measured spectrum, therefore, the most suitable method should be applied.

3. Conclusions

In this study, we developed software that enables the control of a multi-channel radiation detector and analysis of measurement data. Detector control was developed to concurrently manage multi-channel CZT sensors, enhancing user convenience. Measurement data analysis can be monitored individually or simultaneously in real-time. On the individual CZT measurement data analysis screen, it is possible to identify the presence of peaks corresponding to nuclides. The software automatically calculates the Integral, the ROI area, the FWHM, and the FWTM for those peaks.

To verify the performance of the software, an evaluation was conducted using a Cs-137 radiation source. The results were compared with those of commercial software that utilizes a different FWHM calculation method. The comparison shows similar FWHM, but noticeable differences in FWTM.

Since there is a difference between the two calculation methods, a method suitable for the measurement environment must be applied. We plan to conduct additional experiments and data analysis, as well as optimize the software to achieve accurate nuclide identification. Additional analysis functions for measurement data are also planned to be added in the future.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT). (No.2020M2D2A2062538)

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