The Real-Time Monitoring of Dose Rate and Radioactivity Using an Environmental Radiation Monitor Based on the NaI(Tl) Detector

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1. Introduction

In general, the high pressure ion chamber (HPIC) and GM (Geiger Muller) counter are widely used as a radiation detector for monitoring the ambient dose rate in the environment as well as the nuclear facility. These detectors have a strength about the reliable and stable measurement of the ambient dose rate. However, the HPIC and GM counter can only give the result of the measured ambient dose rate without the information of the artificial and natural radiation. To overcome this drawback of the HPIC and GM counter, the spectrometric determination of the ambient dose rate is on an increasing trend using a NaI(Tl) scintillation detector. The dose conversion algorithm by the detector used should be prepared in advance to convert the measured energy spectrum for counts into the ambient dose rate.

In this study, an environmental radiation monitor (ERM) based on a 3”x3” NaI(Tl) detector (EFRD3300, SI Detection Co. Ltd., Korea) was applied to perform real-time monitoring of the dose rate and radioactivity for detected gamma nuclides around an ERM by using the dose rate spectroscopy [1-3]. First, the dose rate and radioactivity for detected natural radionuclides using an ERM based on a 3”x3” NaI(Tl) detector were experimentally verified by comparing with them of in situ gamma-ray spectrometry results obtained by a portable HPGe detector and the analysis of samples taken around an ERM. Finally, an ERM with dose rate spectroscopy was used for the real-time monitoring of two variables around the ERM by reporting them every 15 minutes.

2. Method and Results

2.1 Dose rate spectroscopy

The dose rate spectroscopy is first introduced to calculate the individual dose rate for detected gamma nuclides from the environment as well as radioactive materials. This method was expended to infer the radioactivity from the calculated individual dose rate for detected gamma nuclides by using the dose-to-curie (DTC) conversion method. To use the dose rate spectroscopy, the measured energy spectrum for count rate from an ERM was converted into one for dose rate by multiplying the count rate and dose conversion factor, such as a G(E) in the unit of nGy/h/cps, as shown in Fig. 1.

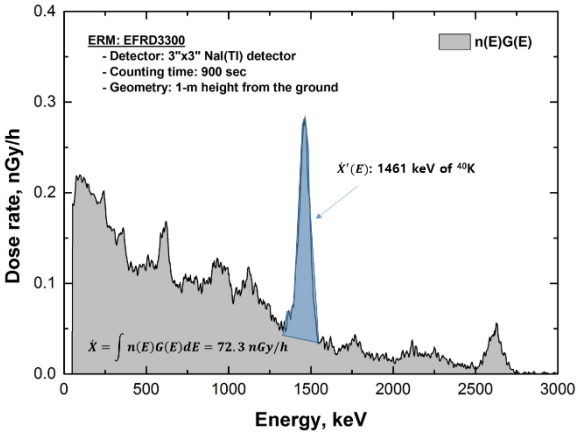

Fig. 1. The energy spectrum for dose rate measured from an EFRD3300.

2.2 Mathematical expression

In the case of a nuclide with a single photon energy, its individual dose rate can be shown in Eq. (1). If a nuclide has several gamma-rays and the contribution ratio of one gamma-ray to the individual dose rate is

calculated, its individual dose rate can be calculated as Eq. (2). Finally, the radioactivity in the ground can be estimated by dividing the calculated individual dose rate into the dose rate per unit curie, d_i, at 1 m above the ground due to the homogeneous distribution of natural radionuclides, as shown in Eq. (3).

$$\dot{X}(E) = \int_{E_n}^{E_m} \frac{n'(E)G(E)W^{-1}(E)}{DP(E)} dE \quad (1)$$

$$\dot{X}_i = \frac{\dot{X}(E)}{CR_i(E)} \quad (2)$$

$$A_i = \frac{\dot{X}_i}{d_i} \quad (3)$$

where, E_n and E_m are the lower and upper bounds of a peak, X(E) is the dose rate induced from a gamma-ray with an energy E, DP(E) is the peak-to-total ratio in the energy spectrum for the dose rate, W(E) is the angular correction factor for the G-factor, X_i is the individual dose rate of nuclide i, $CR_i(E)$ is the contribution ratio of one gamma-ray to the individual dose rate of nuclide i, and A_i is the radioactivity in the ground.

2.3 Experimental verifications

The calculation results of the radioactivity using the ERM were verified by comparing with results from a portable HPGe detector and the sample analysis results taken from the soil around the ERM, as shown in Fig. 2. The used portable HPGe detector uses in situ objective counting system (ISOCS) software (ver. 4.2.1) to calculate the theoretical efficiency in accord with the geometry in the in situ measurement.

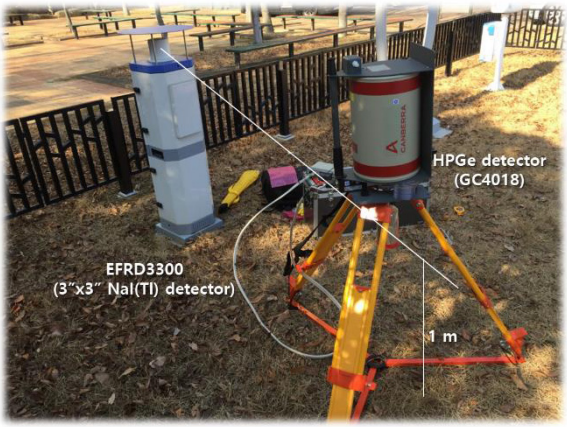

Fig. 2. The in situ gamma-ray spectrometry using a portable HPGe and ERM.

Four natural radionuclides, such as ^{214}Bi, ^{228}Ac, ^{208}Tl, and ^{40}K, were analyzed using an ERM based on a 3”x3” NaI(Tl) detector, by applying the interference correction. All analysis results of the radioactivity of four natural radionuclides in the ground obtained by an ERM using dose rate spectroscopy were within a 20 % difference from those of the analysis sample taken around the ERM.

3. Conclusion

Dose rate spectroscopy was applied to an ERM based on a 3”x3” NaI(Tl) detector to conduct real-time monitoring of the ambient dose rate as well as the individual dose rate and radioactivity for detected gamma nuclides around an ERM. The experimental verification was conducted at two different sites with installed ERMs, and the results were compared to those obtained using a portable HPGe detector and sample analysis. A good agreement between an ERM and sample analysis was achieved in the analysis results of four natural radionuclides in the ground. As a result, it could be concluded that an ERM with a gamma-ray spectrometer can give reliable and stable monitoring results of ambient dose rate as well as individual dose rate and radioactivity of detected gamma nuclides around the ERM.

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