Development of Dose Rate Spectroscopy and Its Application to the In Situ Gamma-Ray Spectrometry

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1. Introduction

A spectrometric determination of the dose rate using a dose conversion factor is a very useful method to get more information from the measurement, such as the nuclide contribution to the ambient dose rate and the individual dose rate for detected gamma nuclides. The calculation method for the individual dose rate for detected gamma nuclides was first suggested by introducing the concept of the dose rate spectroscopy [1-3]. The validity of the suggested method for the individual dose rate was experimentally verified through a comparison of the calculation results on the energy spectra for several conditions of the standard source. Since the individual dose rate for a gamma nuclide is directly related to its activity, it could be expected that this method for calculating the individual dose rate using dose rate spectroscopy will be a very useful means to infer the radioactivity from the environment as well as some radioactive materials.

The dose-to-curie (DTC) conversion method [4-6] is a simple and easy way to estimate the radioactivity based on the measured dose rate from radioactive materials, even though high uncertainty due to numerous assumptions and limitations placed on its use still take effect. This high uncertainty is related to the determination method of variables in the DTC conversion method. However, in the case of using dose rate spectroscopy, the individual dose rate for detected gamma nuclides could make the DTC conversion method simple without the high uncertainty. The experimental verification was then conducted to confirm the method validation of the modified DTC conversion method in the energy, dose rate, and distance range of the gamma nuclides.

2. Methods and Results

The G-factor as the dose conversion factor for two kinds of the gamma-ray spectrometer was used to calculate the dose rate from the measured energy spectrum for counts. A G-factor, G(E), is a function of a detector's response to incident photons and can be calculated from the Monte Carlo simulation.

2.1 Dose conversion factor

In general, the detector response function depends on the detector material and geometry, as well as on the incident photon energy and direction. As shown in Fig. 1, the G-factors for a 3 " x3 " NaI(Tl) detector and portable HPGe detector with a 40 % of the relative efficiency were calculated, respectively, using the MCNP code for parallel and vertical incident photons to the detector axis, respectively.

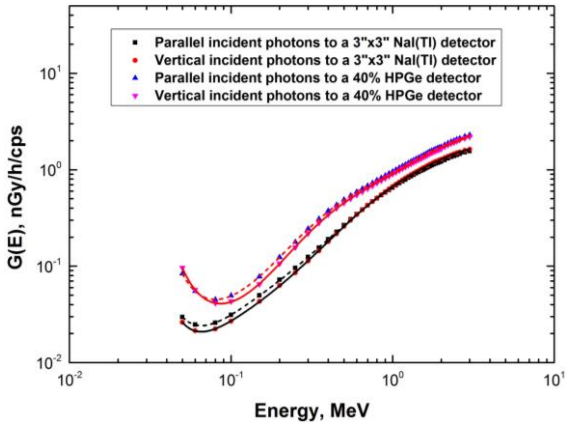

Fig. 1. The G-factor of the 3"x3" NaI(Tl) and HPGe detectors

2.2 Dose rate spectroscopy

To directly calculate the individual dose rate from the energy spectrum, it is very effective to convert the energy spectrum for counts to that for the dose rate, which is just a form of multiplied cps and the value of a G-factor by the energy in the spectrum. Fig. 2 shows the conceptual design for reporting the individual dose rate for detected gamma nuclides from the measured count rate by using a G-factor and peak-to-total ratio.

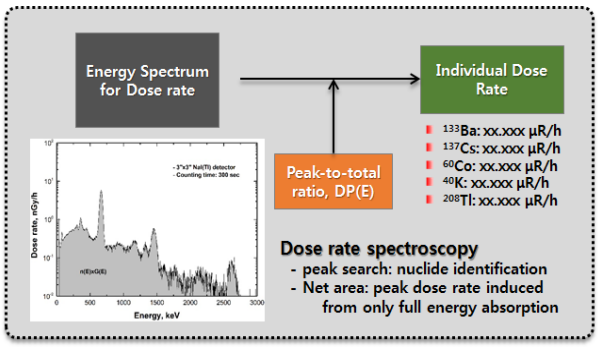

Fig. 2. The conceptual design for dose rate spectroscopy

The DTC conversion method to calculate the activity from the measured dose rate can be simplified by using the individual dose rate for detected gamma nuclides from dose rate spectroscopy, as shown in Eq. (1).

$$A_i = \frac{X_i}{d_i} \quad (1)$$

Where, A_i and X_i are the radioactivity and individual dose rate for detected gamma nuclides, and d_i means the dose rate per unit curie.

2.3 Experimental verification

An improved DTC conversion method using the dose rate spectroscopy was applied to the assay of the simulated radioactive material with a volume of about 1 L, and off-centered nuclides, such as ^{57}Co, ^{137}Cs, and ^{60}Co. As shown in Fig. 3, off-centered nuclides from 0 to 5 cm to the center were made by inserting two kinds of point source of previous linearity experiments into sawdust. The results for the activity calculation of the simulated radioactive material using a modified DTC conversion method were below about 10 % difference, when compared with their certified values.

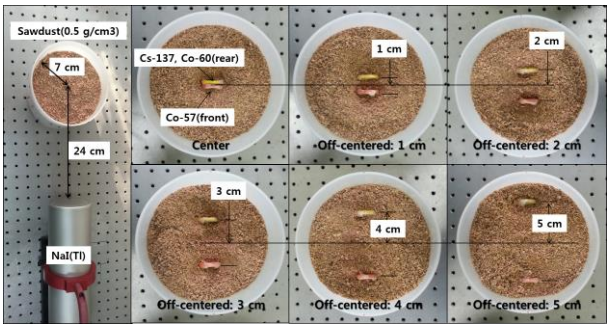

Fig. 3. The geometry of point sources in sawdust and a NaI(Tl) detector

2.4 In-situ gamma-ray spectrometry at the environment

To expand the application of dose rate spectroscopy to the environment, the results of in-situ measurement using a portable HPGe detector (Fig. 4) were re-evaluated by determining the radioactivity of natural radionuclides in the ground from an improved DTC conversion method using dose rate spectroscopy.

Fig. 4. In-situ gamma-ray spectrometry in Jeju Island

Except for ^{212}Pb with low energy of gamma-rays, all results from the dose rate spectroscopy were within a 20 % difference from those of the ISOCS (in-situ objective counting system) in used HPGe detector for the nuclides in the uranium and thorium decay series as well as ^{40}K.

3. Conclusions

The validity of an improved DTC conversion method using dose rate spectroscopy was experimentally verified from the calculation of individual dose rates and radioactivities for detected gamma nuclides in the simulated radioactive materials as well as environment. A good agreement between expected and calculated activities from the modified DTC conversion method was generally kept at even relative low energy and dose rate of ^{57}Co in the simulated radioactive materials. In addition, the results obtained from the dose rate spectroscopy in the environment were also satisfactory and comparable with those from the ISOCS software and the analysis of a sample taken from the soil around a detector.

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