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The detector response and its angular correction of a large-volume NaI(Tl) detector according to the position above the ground

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1. Introduction

The importance of radiation surveys has been increasing from experience about radioactive fallouts after several nuclear accidents. In the case of loading a radiation detector in a vehicle, one of the greatest difficulties is related to the in-situ calibration, in which the count rate measured at some height of a vehicle can be converted to radioactivity at the ground. Therefore, the theoretical determination of the detector response functions at several heights owing to artificial radionuclides released from nuclear accidents can play an excellent role in appropriate and quick response.

In general, the detector response [1, 2] from an incident photon fluence can be estimated from a Monte Carlo simulation. The conditions of an incident photon fluence would then be an important variable to calculate the detector response. In particular, the angular distributions of an incident photon fluence at the detector heights should be first determined and then applied to the calculation of the detector responses at several heights. In addition to the detector height, the impact on the source distributions in the ground has to be evaluated to calculate the detector response, since the angular distributions of an incident photon fluence can be dependent on the diameter of the source distributions in the ground.

In this study, a hexahedral 4"x4"x16" NaI(Tl) scintillation detector was simulated to calculate the angle-corrected detector response from the MCNP code. First, the angular response of the detector used was evaluated for several directions of incident photons owing to the plane source distribution located just in front of a detector. The angular distribution of the photon fluences at several heights, such as 1 m, 50 m, 100 m, 200 m, and 300 m, was then calculated for photons crossing the detector window owing to several source distributions in the ground. Finally, angular correction factors for a hexahedral NaI(Tl) detector can be obtained from the angular responses of a detector owing to incident photon fluences with angular distributions according to the detector heights.

2. Methods and Results

2.1 Environmental Radiation Survey System

The environmental radiation survey (ERS) system, as shown in Fig. 1, was developed for dose rate mapping on the ground from measured data by loading it in several kinds of vehicles. This system consists of a hexahedral 4"x4"x16" NaI(Tl) detector, photomultiplier (PMT) and multichannel analyzer (MCA), controller, GPS, and battery.

Fig. 1. Environmental radiation survey system

2.2 Detector Response

The detector response for a hexahedral 4"x4"x16" NaI(Tl) scintillation detector was calculated for incident photons with several energies and angles, such as 0, 15, 30, 45, 60, 75, and 85 degrees along with two kinds of axes, which indicate the x- and y-directions. Fig. 2 shows examples of the MCNP modeling of incident photons to the detector with an angle of 45 degree at two directions.

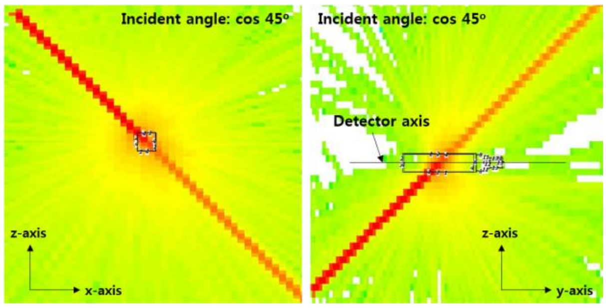

Fig. 2. The MCNP modeling concept of incident photons to the detector

First, the detector response for vertically incident photons to the detector axis was calculated for several photon energies. In the MCNP calculation, the F8 tally (pulse height tally) was used to obtain theoretical energy spectra according to the incident photon energy. The net count rate was then calculated in the energy spectrum. The results of a detector response by the photon energy are shown in Fig. 3 as representing those to the log-log scale and applying the polynomial regression with a 6^{th} order.

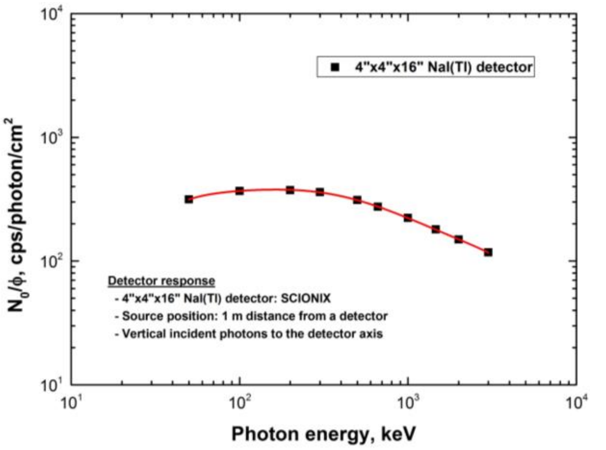

Fig. 3. The detector response of a 4"x4"x16" NaI(Tl) detector for vertically incident photons to the detector axis

2.3 Angular Correction Factor

The mathematical expression for calculating the angular correction factor, W, is shown in Eq. (1).

$$W = \frac{N_\theta}{N_0} = \frac{\int R(\omega)\gamma(\omega)d\omega}{\int \gamma(\omega)d\omega} \qquad (1)$$

Where, N_θ and N_0 are the net count rate for incident photons with a certain cosine angle and normal incidence, ω is the cosine angle, R(ω) is the angular dependence for the detector response, which is the ratio of the net count rates for incident photons at an angle ω and normal incidence (ω=0), and γ(ω) is the distribution of unscattered photons crossing the detector window with an angle of ω, which was calculated from the F5 tally of MCNP code. The angular dependence for the detector response of a 4"x4"x16" NaI(Tl) detector was calculated using the results of the detector response calculation according to the photon energy and its incident angle, as shown in Fig. 4.

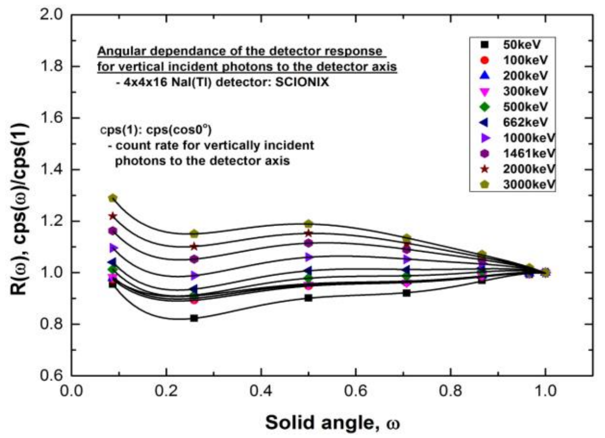

Fig. 4. The angular dependence for the detector response

As a result, the angular correction factor was then calculated from Eq. (1). Since angular distributions of a photon fluence generally have similar forms when increasing the source radius above the detector height at all calculation heights [3], the angular correction factor will be nearly independent on the source distributions at the surface except for local contaminations if a detector is operated at a sufficient height.

3. Conclusions

The detector response and its angular correction of a hexahedral 4"x4"x16" NaI(Tl) detector was calculated using the MCNP code. The theoretical energy spectra for incident photon fluence were obtained for several photon energies. From the net count rate in the simulated energy spectrum, the detector response was then calculated for vertically incident photons to the detector axis. The angular dependence of the detector response was also simulated by changing the cosine angle of incident photons in the x- and y-directions. Finally, the angular correction factor was calculated from the angular dependence of the detector response and the angular distribution of incident photons at the position of a detector.

ACKNOWLEDGMENTS

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