A Method for Simultaneously Determining the Depth and Radioactivity of an Embedded Source in a Medium

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1. Introduction

There are many approaches to estimating the depth of an embedded source in a medium, such as a multiple-photopeak method [1], peak-to-valley method [2], and collimation method [3-4]. However, these approaches have certain limitations, such as multiple gamma-rays from a source, and multiple measurements with and without collimators and lead plates. Above all, a severe limitation is to not give information for the radioactivity in the embedded source without an expensive in-situ program. This study therefore focuses on the development of a simple and advanced algorithm to simultaneously estimate the depth of an embedded source and its radioactivity in the medium. A simple program equipped with an algorithm for the simultaneous determination of two variables was developed by establishing a database for the results from a Monte Carlo simulation for unscattered photon fluences at several geometries and detector response according to the photon energy.

The method was then designed to determine the source depth and its radioactivity in the medium using theoretically calculated photon fluence and measured count rate from the in situ measurement. The existing method [4] to determine the source depth demands the information on the effective center of a detector so that this method depends on the type of a detector. In addition, the expensive in-situ program should be prepared to evaluate the radioactivity of the embedded source. This makes severe time and cost constrain. Therefore, the developed method is focusing on the new and simple algorithm without the dependence on the detector to find out the source depth in the medium and the application of the results to the calculation of the radioactivity of the embedded source. In addition, the purpose of this method is to easily use it by operating the whole process from finding out the source depth to calculating the radioactivity on the basis of Excel program.

2. Methods and Results

2.1 Source depth and its radioactivity

A mathematical expression to calculate the depth of an embedded source in a medium can be written to be form of Eq. (1), according to Al-Ghamdi's approach [4], and its schematic diagram is shown in Fig. 1. This method can give a reliable estimation of the source depth in the ground. However, there is no information of the radioactivity of an embedded source. To calculate its activity, it is necessary to use other program of the in situ gamma-ray spectrometry, such as ISOCS (in situ objective counting system, Canberra Inc.) or ISOTOPIC (Ortec Inc.).

$$\frac{cps_1}{cps_2} = \frac{\varphi_1}{\varphi_2} \approx \frac{(d+l_2)^2}{(d+l_1)^2} = \frac{(d+h_2+c)^2}{(d+h_1+c)^2} \quad (1)$$

where, indexes 1 and 2 mean the detector position from the surface of the medium, cps is the net count rate measured by the gamma-ray spectrometry, φ is the unscattered photon fluence, d is the depth of an embedded source in the medium, *l* is the distance from the surface of the medium to the effective center of the detector volume, h is the distance from the surface of the medium to the front surface of the detector, and c is the distance to the effective center from the front surface of the detector.

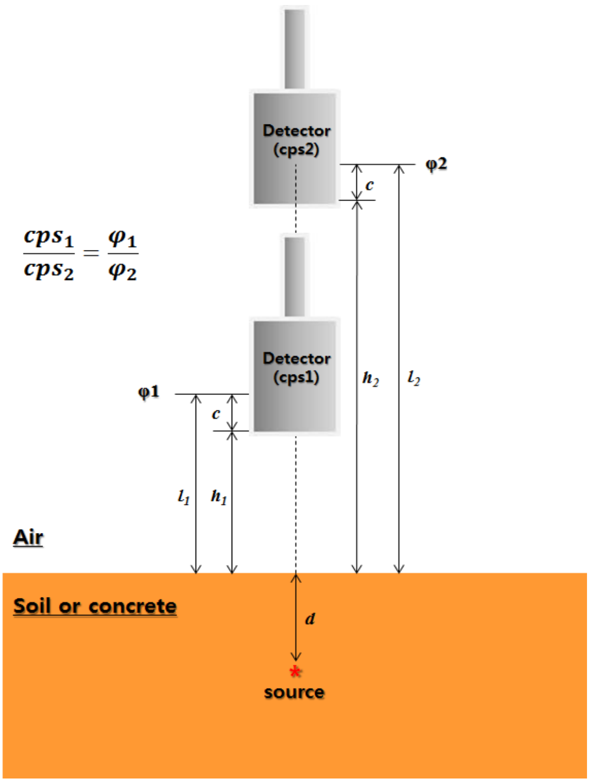


Fig. 1. The geometry between a source and a detector

2.2 Program development

Unscattered photon fluences were first calculated at several source depths in the medium as well as detector positions from the MCNP code, and then established as a database to output their values by inputting the photon energy, depth in the medium, and detector height. After determining the source depth by comparing the fluence ratios to three detector heights, the incident photon fluence from the source depth determined and detector response, which can be estimated from the MCNP code, are used to find out its radioactivity in the medium. Therefore, this algorithm can provide a clue to solve the source depth and its radioactivity from the information on the measured net count rates at the detector heights. The developed program based on the Excel VBA (visual basic application) is shown Fig. 2 and 3.

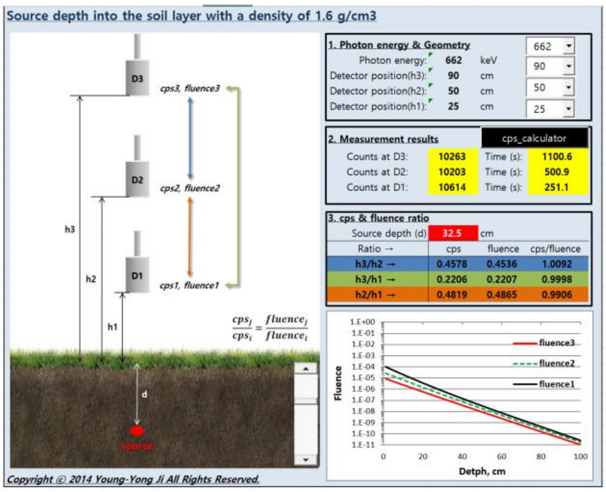
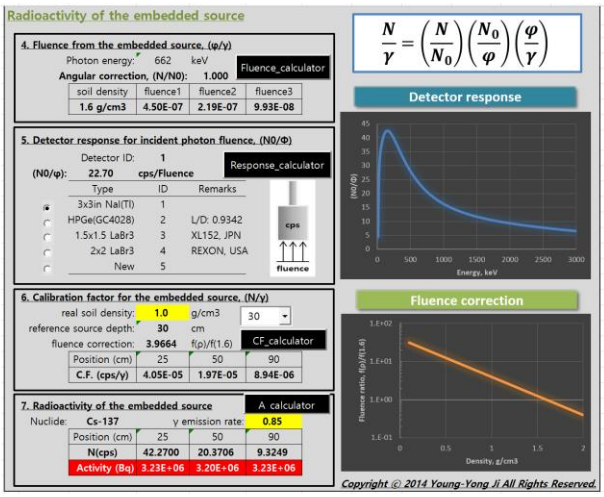


Fig. 2. The determination of the source depth using the Excel VBA



$$\frac{N}{\gamma} = \left(\frac{N}{N_0}\right)\left(\frac{N_0}{\varphi}\right)\left(\frac{\varphi}{\gamma}\right)$$

Fig. 3. A program for the determination of the radioactivity using the Excel VBA

A simple developed program for the simultaneous determination of two variables was applied to the calculation of the depth and activity of ^{134}Cs and ^{137}Cs, which were embedded in the ground, through the in-situ gamma-ray spectrometry. For example, net count rates at three heights above the ground were first measured using a HPGe detector. The embedded depth of ^{137}Cs was then estimated by comparing the fluence database at sever depths and heights, as shown in Fig 2. Finally, the radioactivity of ^{137}Cs embedded in the depth of 32.5 cm was calculated to be about 3.22 MBq by manually inputting the real density of the medium of 1.0 g/cm^3, as shown in Fig. 3. Lower than 10 % and 15 % differences compared with the real values at the source depth and radioactivity, respectively, were achieved using the program developed without any other expensive commercial in situ software.

3. Conclusions

A simple program equipped with an algorithm regarding the simultaneous determination of the embedded source depth and its radioactivity was developed based on the Excel VBA. The program was then applied to the results on the in situ gamma-ray spectrometry using a HPGe detector to find the depth and activity of ^{134}Cs and ^{137}Cs. Good agreements at the source depth as well as the radioactivity between the estimated and calculated values were achieved less than 10 % and 15 % differences compared with the real values using the developed program. In the feasibility on the application of the developed program to the general situation regarding the source distribution, this program still had an effect on the estimation of the depth and activity in the maximum strength of diffused sources into a layer.

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