The Quantitative Analysis of Uranium and Thorium in Soil Using HPGe Gamma-Ray Spectrometry

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1. Introduction

Alpha spectrometry and ICP-MS (Inductively Coupled Plasma Mass Spectrometry) have been widely used to determine the radio-activities of ^{238}U and ^{232}Th. Even though these methods are useful to assess low level radioisotopes, several pretreatment are required to know the amounts of nuclides in the soil [1].

HPGe gamma-ray spectrometry needs simple preparation to determine the quantitative analysis of uranium and thorium by measuring their decay products in the soil [2]. According to the decay schemes of ^{238}U and ^{232}Th, the daughter nuclides are ^{214}Pb, ^{214}Bi, and ^{228}Ac. They should be measured using gamma-ray spectrometry to use secular equilibrium [1,2].

The purpose of this study is to perform the quantitative analysis of the concentration of ^{238}U and ^{232}Th in the soil using HPGe gamma-ray detector.

2. Materials & Method

The experiment was carried out using a coaxial p-type HPGe detector (ORTEC, GEM20P4-70). The relative efficiency is 20%. The resolution and the Peak-to-Compton ratio are 1.8 keV and 52:1 at 1.33 MeV, respectively. The software to collect and analyze the gamma-ray spectra is Gamma Vision.

2.1 Calibration

The energy and efficiency calibration were conducted using 1 L marinelli beaker standard source. The type of standard source is agar from KRISS. 10 types of nuclides, ^{241}Am, ^{109}Cd, ^{57}Co, and etc., are included in the standard source.

An empty marinelli beaker was also measured for 24 hours to consider the peaked background correction [3].

2.2 Sample preparation

The soil sample was collected from the specific site located near Kyunghee University. After the miscellaneous substances like pebbles and branches were sifted out, the sample was dried in the drying oven at 150°C for 50 hours. Following the dryness, the sample was sieved with fine sieve to reduce the void. The dried sample was sealed in 1 L marinelli beaker [4]. The processes for sample preparation are shown in Fig. 1.

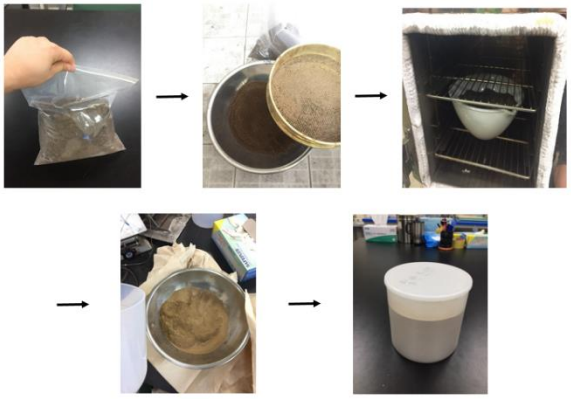

Fig. 1. The processes of sample preparation for gamma-ray detection.

2.3 Decay schemes

The decay schemes of ^{238}U and ^{232}Th are illustrated in Fig. 2. The sample was stored during 20 days to reach the secular equilibrium. In order to know the activity of ^{238}U, the activities of ^{214}Pb (351 keV) and ^{214}Bi (1120 keV, 1764 keV) were measured. The activity of ^{228}Ac (968 keV) was also measured to know the activity of ^{232}Th [4].

Fig. 2. The decay schemes of uranium and thorium.

3. Results

The sample was measured for 24 hours and the counts were acquired with Gamma Vision. The sample was also detected several times at same condition to know the average and standard deviation. The specific activities of ^{238}U, ^{232}Th and ^{40}K, which is commonly detected at 1460 keV, were calculated using the Absolute Method [4].

$$A = \frac{CPS_{net}}{\varepsilon \cdot I \cdot m}\ (Bq/kg) \quad (1)$$

where CPS_{net} is the net count rates of nuclides, ε is the efficiency of energy, I is the photon yield or emission probabilities, and m is the mass of sample in kg.

Table 1 indicates the specific activities of ^{238}U and ^{232}Th using Eq. (1).

Table 1. The values of specific activities at each of the energies

	Energy (keV)	Activity (Bq / kg)
^{238}U	351	23.61 ± 0.90
	1120	26.83 ± 1.34
	1764	29.17 ± 0.12
^{232}Th	968	63.89 ± 1.16
^{40}K	1460	854.92 ± 18.27

4. Conclusion

The experiment was carried out to know the activities of ^{238}U and ^{232}Th using Absolute Method.

There are several advantages to use HPGe detector instead of alpha spectrometry. The sample for gamma-ray spectrometry doesn't need complicated pretreatment processes comparing with the alpha spectrometry, which makes lots of waste.

However, it is required to compare the quantitative analysis of uranium and thorium using alpha spectrometry with our results. Because the natural soil used for our experiment had low level radioactivity and uncertainty.

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