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Measurement of MDA by Chemical Composition of Soil Samples by Compton Suppression

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1. Introduction

In environmental radioactivity measurements, if the sample's radioactivity concentration is sufficiently higher than the background, there is no problem. However, if it is similar to the background concentration, overlapping areas occur, which limits the measurement of the actual radioactivity concentration. When the amount of sample is very small, it becomes difficult to distinguish the signal from the background, which poses a problem of limits to the amount of radioactivity that can be measured. When the amount of sample is very small, it becomes difficult to distinguish the signal from the background, which poses a problem of limits to the amount of radioactivity that can be measured. Therefore, in this study, the amount of samples and measurement time are changed using soil samples, and the component ratio is analyzed to analyze the effect on the MDA value.. MDA values were measured by effectively removing interfering nuclides of cesium isotopes using chemical pretreatment from the sample, and how much can be reduced through Compton suppression is to be compared and analyzed.

2. Methods and Results

2.1 Compton suppression system

The Compton suppression system is a device that suppresses regions that exist as Compton continuum in the spectrum. This has the advantage of clarifying the peak analysis for gamma rays that may exist in the Compton continuum region. In addition, by wrapping the main detector around the main detector with a suppression detector, the shielding effect on the background radiation accompanying gamma ray measurement can also be expected. The Compton inhibition system consists of one HPGe and one NaI(T1) detector. The HPGe detector is inserted at one end of the tube, and the NaI plug detector is inserted at the other end. Samples are placed inside the annulus between the HPGe and NaI detectors.. In order for Compton suppression to occur as effectively as possible, it is necessary to wrap the main detector as much as possible to increase the probability of scattered gamma rays entering the suppression detector, and to use a material with high measurement efficiency for incident gamma rays as a suppression detector.

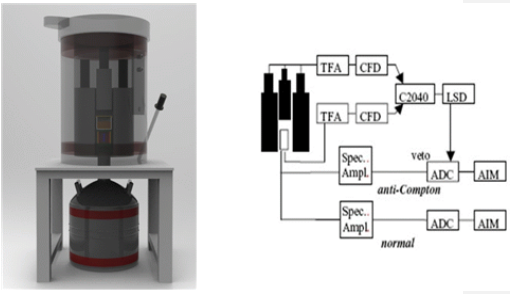

Fig.1. Compton Suppression system (a) and block diagram of the signal processing system (b)

2.2 Penelope simulation of CSS geometry

The main detector used in simulation is a coaxial P-type with a diameter of 64 mm and a length of 71 mm, a FWHM of 1.73 keV for 1332 keV gamma rays, a relative efficiency of 60%, and a Peak-to-Compron Ratio 58:1. It is one auxiliary detector 3"X 3" NaI detector, and it was simulated by coding the geometry file of the detector.

2.3 Compton Suppression Factor

As a representative indicator for quantitatively representing the effect of Compton suppression, it represents the ratio of the energy deposed on the main detector when suppressed and not suppressed for a given gamma-ray energy, and is defined as the following equation (Equation 1).

$$CSF = \frac{(\text{Peak-to- Compton ratio})_{unsuppressed}}{(\text{Peak-to- Compton ratio})_{suppressed}}$$

In the case of nuclides emitting gamma rays, the reduction factor (RF) is used.

$$ARF = \frac{\sum \{(\text{Count})_{unsuppressed} / (\text{Count})_{suppressed}\}}{\text{Total number of channels}}$$

The peak-to-Compton ratio is defined here as the ratio of the total energy peak distribution of gamma rays for the ranges 55-65 keV, 358 keV to 382 keV (Compton plateau), and 461-472 keV (Compton edge) for a power of 661.67 keV.

The above equation shows the average ratio of the count number per channel in the continuum region for the case where Compton suppression occurs and the case where Compton suppression does not occur, and the effect of Compton suppression on the entire gamma-ray energy spectrum region can be confirmed. Each dotted circle was placed at 0.5 cm in the center of a cylindrical beaker between the NaI plug and the HPGe detector window, and it was measured in the energy range of 15 - 700 keV to evaluate SF by ^{137}Cs. In addition, the ^{137}Cs source was measured and the reduction coefficient (RF) was evaluated.

As can be seen from Table 1, as a result of comparing the SF ratio (suppressed and unsuppressed), it can be seen that the reduction factor ratio (RF) significantly decreases as it goes to high energy rather than low energy

2.4 Energy Calibration & Peak- to- Total Calibration

Energy Calibration were corrected using standard mixed gamma source (40 ml CRM) low energy (50 keV) to high energy (3000 keV) and compared with the simulation. Using mixed volume standard source (40 ml), the measured value and Penelope are compared and shown in Fig. 2

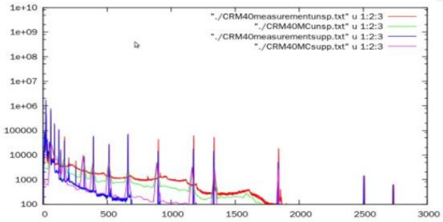

Fig. 2. Comparison of CRM 40ml measured values & Penelope simulation values in CSS

The Compton region, which has the largest energy of 661 keV with a ^{137}Cs photoelectric peak and is spread from approximately 500 keV to the low energy (200 keV) region, was significantly suppressed.

2.5 ^{134}Cs Standard Soil Sample Preparation and Composition Analysis

At the Korea Institute of Standards and Science, ^{134}Cs aqueous source 1) at 37 kBq/kg was diluted in distilled water to prepare a source of 500 Ba/kg, 1,000 Bq/kg, 2,500 Bq/kg, and 5,000 Bq/kg..

As a result of analyzing river soil and surface soil by using XRF, the chemical composition is the same as SiO_2, Al2O$_3$, etc., but the chemical composition ratio varies depending on the type of soil.

2.6 Measurement of MDA of soil samples by Compton Suppression

In order to raise the lower limit of measurements found in environmental samples, it is necessary to improve the detection limit of gamma-ray spectra. The radioactive background of the gamma-ray spectral system can reduce the amount of radioactive nuclides very close to the periphery of the germanium crystal. Two types of pretreated standard soil samples (river soil and surface soil) were measured at 30,000 and 80,000 s, respectively, and the radioactivity concentrations of the anti-Compton and Compton suppression spectra were compared, respectively.10 days after the standard ^{134}Cs soil sample (40 mL) was made, it was directly measured in a cylindrical beaker Through Compton suppression, it was found that the standard sample and the radioactive concentration after correction were almost identical. The MDA results (30000s) according to the chemical composition of the soil sample are shown in Table 1.

메모 포함[L1]:

Table 1. MDA results based on chemical composition ratio of ^{134}Cs soil samples in Compton suppression

Standard	Compton suppression

sample(Bq/kg)	unsuppressed	suppressed	Measurement result (after correction) (Bq/kg)	coposition
500 (482 ± 3)	< 1.89	< 0.84	501 ± 3	SiO_2
1000 (964 ± 3)	< 0.95	< 0.43	1003 ± 1	Al_2O_3
2500 (2410 ± 2)	< 0.61	< 0.33	2501 ± 3	Mgo
5000 (4820 ± 3)	< 1.27	< 0.65	4988 ± 2	Fe_2O_3

Through Compton suppression, it can be seen that the radioactivity concentration after standard sample correction is almost identical, and the uncertainty of 1.8% was confirmed as a result of measuring the highest ratio of surface soil and river soil. The MDA values are found to be somewhat lower in Compton suppression compared with the AMP measurements mentioned in the previous paper.

3. Conclusions

Several factors such as background, sample measurement time, and recovery rate affect MDA values, especially when the radioactive concentration is more than 2500 Bq/kg, MDA values can be reduced by shortening the measurement time. As the sample amount increased, the efficiency decreased clearly due to the self-absorption effect. Therefore, it was confirmed that the higher the soil type and component ratio, the more the radioactive concentration was affected. The use of Compton suppression confirmed that the presence of natural or artificial radioactive nuclides was useful in the microscopic measurement of some radioactive nuclides contained in environmental samples causing the rise of Compton continuum.

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