# Performance Test of Compton Suppression System by Measurement of Multi-nuclide Standard Source and an Analysis of Biological Reference Materials

J. H. Moon*, G. M. Sun, S. H. Kim, Y. S. Chung
[a] *Korea Atomic Energy Research Institute, Daeduk-Daero 989-111, Dukjin-dong, Yuseong-gu, Daejeon, Korea*
*Corresponding author: jhmoon1@kaeri.re.kr*

## 1. Introduction

Compton scattering is one of major sources to induce a high background when a gamma-ray spectrum is acquired from a radioactive sample. The high background spectrum deteriorates detection sensitivity for an analysis of an interesting nuclide. To improve detection sensitivity by the reduction of spectrum background, a Compton suppression system (CSS) applying an anti-coincidence mode was developed and has been used for a neutron activation analysis [1,2].

This study was used to evaluate the performance of the CSS experimentally by based on the measurement of the gamma-ray emitting source and of detectable nuclides created thorough neutron activation. Five biological standard reference materials (SRMs) were chosen and irradiated by using an NAA#1 irradiation hole at the HANARO. Gamma-ray spectra with normal mode and anti-coincidence mode were acquired at the same time, and advantage factors of CSS for each nuclide detected were calculated on the basis of signal-to-noise ratio.

## 2. Experiments

### *2.1 Measurement of Multi-nuclide Standard Source*

Gamma-ray spectra with normal and anti-coincidence modes were acquired by using a multi-nuclide standard source (Eckert & Ziegler, Isotope Products, GF-ML series). This source consists of ten nuclides, $^{241}$Am (60 keV), $^{109}$Cd (88 keV), $^{57}$Co (122 keV, 136 keV), $^{123m}$Te (159 keV), $^{51}$Cr (320 keV), $^{113}$Sn (392 keV), $^{85}$Sr (514 keV), $^{137}$Cs (662 keV), $^{88}$Y (898 keV, 1836 keV), and $^{60}$Co (1173 keV, 1332 keV), with an activity of 200 kBq on Sep. 2009. The spectra were obtained at five different positions, where the distance from the HPGe detector end cap were 2.0 cm, 5.5 cm, 9.5 cm, 13.5 cm and 20.5 cm. Figure 3 shows the spectra at the distance of 13.5 cm from detector end cap. The net and background areas for interesting gamma-ray peaks of each nuclide in the measured spectrum were gained to evaluate the performance of CSS.

### *2.2 Biological Reference Materials*

For the performance evaluation of CSS for NAA, four geological and five biological SRMs produced by National Institute of Standards and Technology (NIST) in USA were selected. The biological SRMs were 1547-peach leaves, 1548-total diet, 1566b-oyster tissue, 1567a-wheat flour and 1568a-rice flour. Approximately 100 mg of SRM samples for short irradiation(~ 30 s) and 200 mg for long irradiation (~ 2 hrs) were put into polyethylene vials for neutron irradiation. The prepared samples were irradiated by using NAA#1 irradiation hole at the HANARO research reactor. Gamma-ray measurements of the irradiated samples by normal and anti-coincidence modes were executed on the basis of a routine NAA.

## 3. Results and Discussion

### *3.1 Evaluation with Standard Source*

Net and background areas are obtained by an analysis of gamma-ray peaks in the measured spectrum. Table 1 summarizes the ratio of net area with anti-coincidence to normal mode according to measurement position, nuclides and gamma-ray energies. The significant reduction of net area for $^{88}$Y and $^{60}$Co nuclides in an anti-coincidence spectrum is observed when the standard source was measured in closer positions to HPGe detector. This result can be interpreted that two main gamma-rays emanated from $^{88}$Y and $^{60}$Co nuclides increase the probability of coincidence events by the interaction with BGO detectors, and leading to a loss of net counts in an anti-coincidence mode.

Table 1. Ratio of net area with anti-coincidence to normal mode according to measurement position

| Nuclide | Energy (keV) | 2cm | 5.5cm | 9.5cm | 13.5cm | 20.5cm |
|---|---|---|---|---|---|---|
| $^{109}$Cd | 88 | 1.01 | 0.99 | 0.96 | 0.99 | 0.97 |
| $^{57}$Co | 122 | 1.02 | 1.01 | 0.99 | 1.04 | 0.99 |
| $^{123m}$Te | 159 | 1.06 | 1.04 | 0.99 | 1.03 | 0.99 |
| $^{113}$Sn | 392 | 0.99 | 1.03 | 0.99 | 1.03 | 0.99 |
| $^{85}$Sr | 514 | 1.05 | 1.02 | 0.98 | 1.06 | 1.02 |
| $^{137}$Cs | 662 | 1.00 | 1.00 | 0.99 | 1.03 | 0.99 |
| $^{88}$Y | 898 | 0.72 | 0.83 | 0.91 | 0.97 | 0.99 |
| $^{60}$Co | 1173 | 0.72 | 0.80 | 0.88 | 0.96 | 0.98 |
| $^{60}$Co | 1332 | 0.71 | 0.79 | 0.89 | 0.96 | 0.98 |
| $^{88}$Y | 1836 | 0.71 | 0.79 | 0.89 | 0.96 | 0.97 |

Background reduction raio(%) by anti-coincidence mode was calculated according to measurement position, nuclides and gamma-ray energies. The

highest energy peak, 1836 keV of $^{88}Y$, is not considered in this discussion due to no impact on the background reduction by anti-coincidence mode. The results are shown in Figure 1. 898 keV of $^{88}Y$ shows the highest background reducton ratio, at 68%, and 88keV of $^{109}Cd$ shows the lowest, at 17%. Since the reduction ratio is higher than 40% in the energy range above 130 keV, it is demonstrated that CSS is effectively applied to the gamma-ray measurement for NAA.

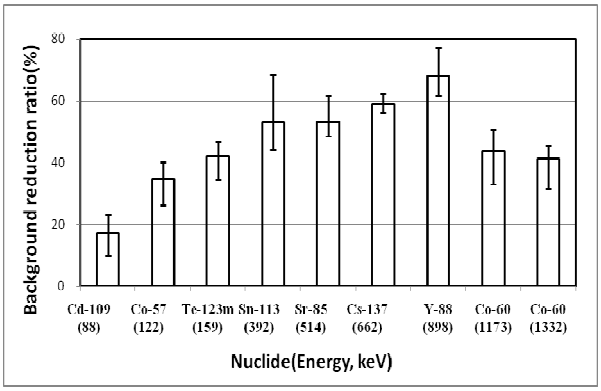


Fig. 1. Background reduction ratio by anti-coincidence mode

### *3.2 Evaluation with Reference Materials*

Nine short-lived nuclides were detected from five biological SRMs and AF values are shown in Figure 2. Most of AF values are placed between 1 and 2. 617 keV of Br-80 from 1567a-wheat flour has the highest AF value, at 3.25, and 1524 keV of K-42 from 1568a-rice flour, 1779 keV of Al-28 from 1566b-oyster tissue and 1810 keV of Mn-56 have AF values higher than 2. 1014 keV of Mg-27 from 1547-peach leaves has the lowest AF value, at 1.17.

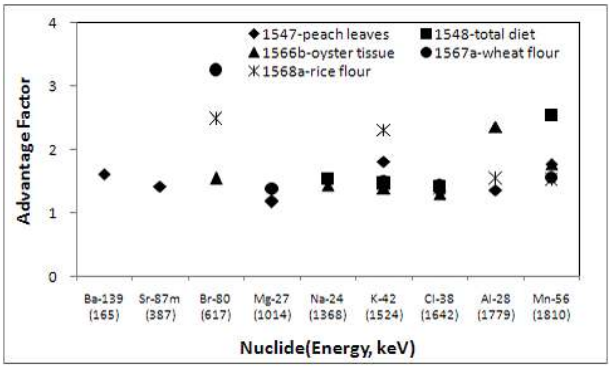


Fig. 2. AF values for short-lived nuclides from biological reference materials.

Seven medium-lived nuclides were detectable, and AF values are shown in Figure 3. AF values of Br-82 for 1566b-rice flour and 1568a-rice flour were calculated by using 776 keV of Br-82 because of the interference with 559 keV of As-76. 559 keV of As-76 from 1568a-rice flour has the highest AF value, at 3.07.

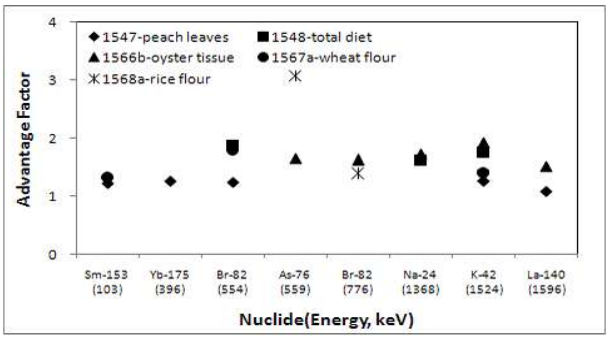


Fig. 3. AF values for medium-lived nuclides from biological reference materials.

AF values for eighteen long-lived nuclides were indicated in Figure 4. Fifteen nuclides were detectable from 1547-peach leaves and 796 keV of Cs-134 has the highest AF Value, at 2.95, and 145 keV of Ce-141 has the lowest, at 1.30. 1332 keV of Co-60 from 1548-total diet has AF value lower than unity.

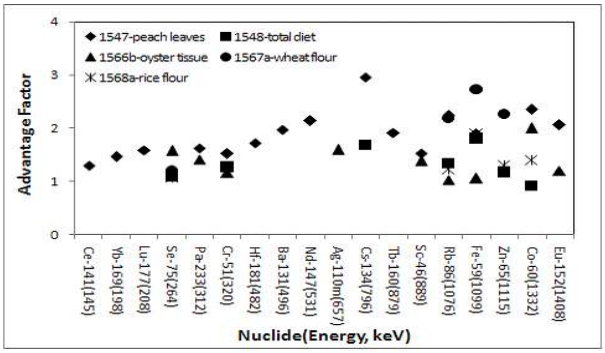


Fig. 4. AF values for medium-lived nuclides from biological reference materials.

## 4. Conclusions

The performance of CSS was evaluated. Background reduction by CSS can reach up to 68% with multi-nuclide gamma-ray emitting source. The mean AF value for the nuclides detected from five biological SRMS was 1.63. The CSS will be applied to the routine NAA of actual samples.

## REFERENCES

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