A Simple Method of Spectrum Processing for β-ray Measurement without Pretreatment

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1. Introduction

Radioactivity analysis of β-emitting radionuclide is important because of its dangerousness of overexposure. In general, γ-ray is accompanied during β decay but few radionuclides which are called as "pure β emitter" emit β-ray only. γ-ray has been measured by conventional detector such as NaI(Tl) or high purity germanium (HPGe) detector. But β-ray is hard to detect by those detectors because of its short range. Therefore, liquid scintillation counter (LSC) has been used to measure the radioactivity of pure beta emitter but there is huge problem of organic waste production, though LSC has high efficiency for detection of low energy β-ray [1].

To solve this problem, characterization of β-ray measurement in a plastic scintillator was carried out in this study. There have been some studies about plastic scintillator to measure the β-rays without liquid scintillation method. Plastic scintillator has benefits for detection of β-ray because it has relative low effective atomic number [2]. β-ray and γ-ray spectra in cylindrical plastic scintillator was analyzed and a method of separation of β-ray spectrum was suggested.

2. Methods and Materials

2.1. Concept of β-ray Spectrum Separation

In case of γ-ray measurement by plastic scintillator, there is no photo absorption peak but Compton continuum in pulse height spectrum. Therefore, the γ-ray database should be stored as continuous spectrum not as a specific energy.

The γ-ray spectrum database was measured by using γ-ray disc sources. The spectra contributed by γ-ray were subtracted from the spectrum for a sample.

2.2. Experimental Setup

A plastic scintillator based detector which was used in this study. A 14-pin PMT (R878, Hamamatsu photonics) was coupled in a PMT tube base with integrated bias supply, preamplifier, and 1024 channel digital MCA (digiBASE, Ortec). A cylindrical plastic scintillator (BC-428, Saint-Gobain Crystals) with height of 20 mm and diameter of 12 mm was used. Both PMT and plastic scintillator were covered by Mylar film in order to reduce optical loss where the Mylar film can reflect 98% of incident light.

2.3. Measuring γ-ray and β-ray Spectra

Three disc radioisotope sources were used to acquire spectra. Activity of each source was 0.1 μCi for ^{90}Sr, and 1.0 μCi for ^{137}Cs and ^{60}Co. Date of manufacture for all sources were January 2015. The ^{90}Sr disc source was placed at the side of plastic scintillator with distance of 19.4 mm. ^{137}Cs and ^{60}Co sources were placed at the side of ^{90}Sr disc source when two or more sources were measured simultaneously. The measurement time was 1 hour (3600 s) as live time.

2.4. Establishment of γ-ray Database

The measured spectra were filtered by averaging filter which is defined as equation 1,

$$\sum_{i=1}^{1024} \frac{S(i-j)+S(i-j+1)+\cdots+S(i+j-1)+S(i+j)}{2j+1} \quad (1)$$

where S(i) is number of count in channel 'i', and '2j+1' is size of the filter. In this study, 3, 5, 7 and 9 channel filters were used and compared each other. Those filters were applied to database γ-ray spectra because it is needed to remove statistical fluctuation.

Optimization of filtering was conducted. Chi-square method was applied and it was calculated by equation 2,

$$\chi^2 = \sum_{i=1}^{1024} \left(S_{cal}(i) - S_{exp}(i) \right)^2 \quad (2)$$

where S_{cal} is calculated spectrum and S_{exp} is experimentally measured spectrum. If a condition has smallest chi-square, it will be an optimization point.

3. Results

Figure 1 shows the result of optimization of filter size and number of repetition. The result of 9 channel filter was not included because the calculated χ^2 was too high ($>10^7$). The solid line at the top indicates the χ^2 of no filtration. It always shows higher value than filtered results. When the number of repetition was 1, which means the database spectrum is filtered only once, the 7 channel filter showed the lowest χ^2. However, χ^2 value showed lowest value and rise again while the filtration was repeated. The number of repetition which shows the lowest χ^2 value was 11, 4, and 2 for 3, 5, and 7 channel filter. The lowest χ^2 value was shown in condition of 3 channel filter and it was repeated for 11 times.

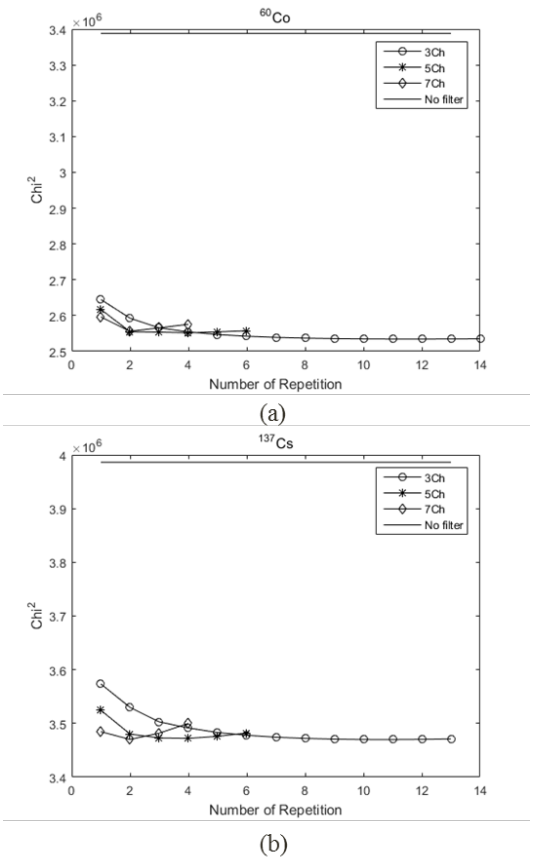

Fig 1. χ^2 calculation result by changing of size of filter and number of repetition

Figure 2 shows the result of constructed β-ray spectrum. The β-ray spectrum of ^{90}Sr (first labeled or blue line) was clearly shown where the contribution of both 90Sr and 90Y was clearly come out. The measured spectrum (second labeled or orange line) was reconstructed well as calculated β-ray spectrum (third labeled or yellow line). The constructed spectrum which was calculated by filtered database γ-ray (fourth labeled or purple line) well overlapped over the β-ray spectrum of ^{90}Sr.

The suggested method was successfully applied for disc standard source. The main cause of error would be shape of spectrum. The successful result was accomplished because the radioactivity of the source was enough strong and the shape of spectrum was made up very nicely. If the number of particles is fewer, the shape of spectrum will be influenced by statistical fluctuation. The only filter used in this study was averaging filter. Other filters, such as Gaussian filter, can be considered for this study.

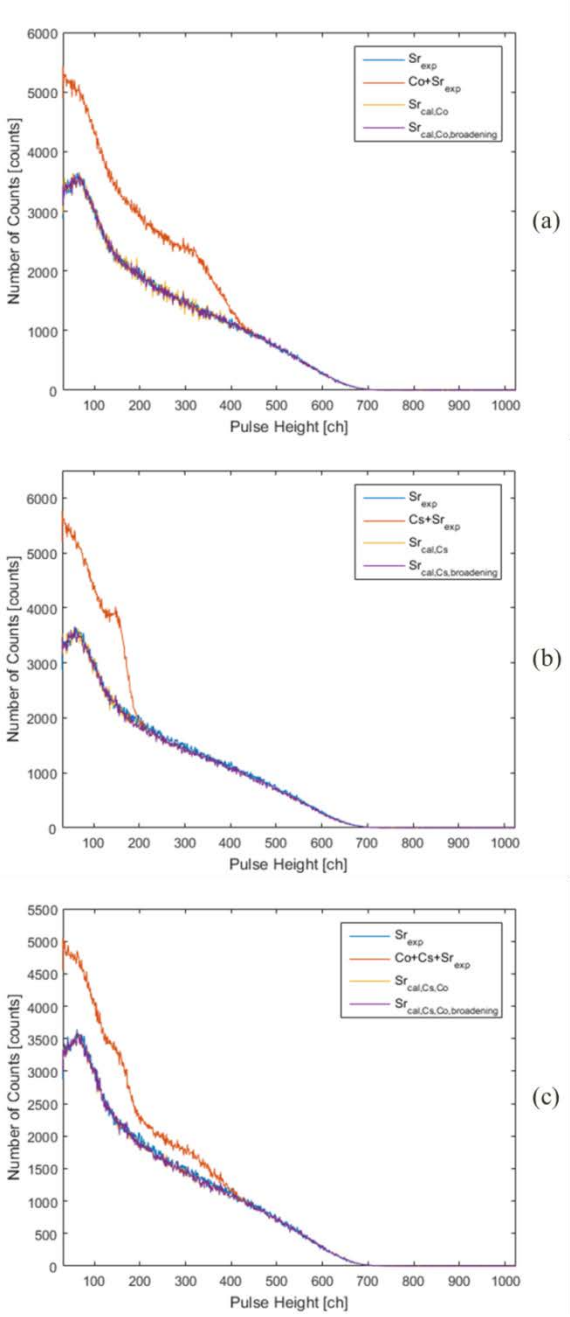

Fig. 4. Measured β-ray spectrum, constructed β-ray spectrum, and original measured spectrum. (a) ^{60}Co (b) ^{137}Cs and (c) combined ^{60}Co and ^{137}Cs

4. Conclusion

A simple method of β-ray spectrum separation was suggested. The method was verified by chi-square method to estimate the difference between calculated and measured spectrum. This method was successfully applied by using disc source. For future works, practical radioactive source will be used to acquire the pulse height spectrum. The method can be used for measurement of pure β emitter without pretreatment if this method is verified for practical purpose.

REFERENCES

[1] Hirokazu Miyoshi and Toshiji Ikeda, “Preparation of Paper Scintillator for Detecting 3H Contaminant” Radiat. Prot. Dosimetry, Vol. 156, No. 3, pp. 277-282, 2013.
[2] Etsuko Furuta, Takao Kawana, “A plastic scintillation counter prototype” Appl. Radiat. Isot., Vol. 10, No. 4, pp. 175-180, 2015.