Beta-Ray and Gamma-Ray Detection Technique for the Soil Surface Using Plastic Scintillators

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1. Introduction

Monitoring of residual radioactivity in the decommissioning site is one of the important technology included in the remediation step of the site. The conventional gamma-ray detector is hard to detect beta-ray because of protecting material to protect scintillator from moisture and oxidation. Because Geiger-Müller counter has no energy resolution, it is impossible to discriminate the type of particle. To overcome these weaknesses of conventional detector, a phoswich detector which used combination of scintillator and pulse shape analysis (PSA) was developed but it had problem of overlap between beta and gamma-ray [1].

In this study, beta-ray and gamma-ray discrimination technique using plastic scintillators with different thickness. The previous study was carried out using combination of two scintillators, plastic scintillator and cadmium tungstate [2]. The study showed the ability of discrimination but the energy calibration between two scintillators was very hard because light outputs of the scintillator are different. Thus, the same scintillators, plastic scintillator, were used in the study except for the thickness.

2. Materials and Methods

2.1 Concept of sensitivity ratio

For a gamma-ray, linear attenuation coefficient of a medium is highly related to the gamma-ray detection efficiency. By the way, detection efficiency of beta-ray is not significantly depending on the medium because the range of beta-ray is short enough where the range of 2 MeV beta-ray was less than 10 mm in the plastic medium. If the thicknesses of scintillators are different, the detection efficiency of gamma-ray would be significantly different while the sensitivity of beta-ray would not.

2.2 Theory and calculation

One scintillator with thickness of 10 mm (Thick) and the other one with thickness of 1 mm (thin) were used in this study. The detection efficiency of each scintillator was experimentally characterized. The sensitivity ratios for the gamma-ray (R_{gamma}) and beta-ray (R_{beta}) were defined as following equations.

$$R_{gamma} = \frac{\varepsilon_{Thick,\ gamma}}{\varepsilon_{thin,\ gamma}} \tag{1}$$

$$R_{beta} = \frac{\varepsilon_{Thick,\ beta}}{\varepsilon_{thin,\ beta}} \tag{2}$$

where $\varepsilon_{a,b}$ was detection efficiency for the type of radiation (b) with different thickness of scintillator (a). The counting rate ratio between two scintillators was utilized to determine the contribution of the beta-ray in the measured counting rate.

$$R_{meas} = \frac{C_{Thick}}{C_{thin}} \tag{3}$$

where C_{Thick} and C_{thin} were counting rates measured by thick and thin scintillators, respectively. The portion of beta-ray contributed counting rate (C_{cal}) could be determined by equation (4).

$$C_{cal} = C_{meas} \cdot X_{\mathrm{meas}} = \mathrm{C}_{\mathrm{meas}} \cdot \frac{R_{gamma} - R_{meas}}{R_{gamma} - R_{beta}} \tag{4}$$

where C_{meas} was counting rate of the sample measured by thick scintillator, X_{meas} was portion of beta-ray contribution which had value between 0 to 1. Related uncertainties were carefully calculated according to the principle of error propagation for the factors causing errors R_{gamma}, R_{meas}, R_{beta}, C_{meas} and background counting rate [3].

2.3 Experimental setup

5 source sets were used to verify the theory. The sources were combination of disc sources and they were described in Table 1. Single ^{60}Co and ^{90}Sr sources were used to characterize the detection efficiency. Combination sources were used to verify the theory to discriminate the beta-ray and gamma-ray contributed counting rate.

Table 1. Information of source sets

Source ID	Composition
Co	Single ^{60}Co (27,209 Bq)
Sr	Single ^{90}Sr (3,456 Bq)
SrCo	One ^{90}Sr and one ^{60}Co.
SrCoCo	One ^{90}Sr (3,456 Bq) and two ^{60}Co (27,209, 17,746 Bq).
SrSrCo	Two ^{90}Sr (3,456, 3,274 Bq) and one ^{60}Co (27,209 Bq)

The prototype detector of was described at Fig. 1. Each plastic scintillator was optically coupled with photomultiplier tube (PMT) and correlated electronic signal processing devices. The soil surface would be scanned by each detector. In this experiment, the disc source sets were departed from the detector by 10 cm and measured by 3 times.

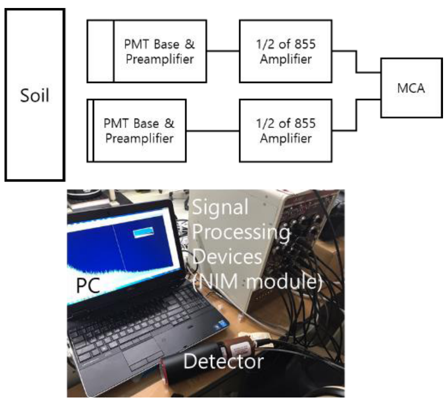

Fig. 1. Scheme of detector composition and its picture.

3. Results and Discussion

The background counting rates for thick and thin scintillator based detector were 803±12 and 398±8 cpm, respectively. Table 2 shows the result of measured counting rates and determined beta-ray contribution. The uncertainty shown in the Table 2 includes uncertainties caused in measurement. The relative uncertainty was increased by 13 times in average during extracting of beta-ray contributed counting rate.

Table 2. Abstract of measurement results

Scintillator type	Source ID	Net Average (cpm)	X_{thick}	Extracted Beta-ray (cpm)
Thick	Co	3,399 ±48	0	0
	Sr	6,068 ±26	1	6,068 ±228
	SrCo	9,557 ±14	0.632	6,040 ±250
	SrCoCo	12,366 ±22	0.468	6,021 ±270
	SrSrCo	16,284 ±32	0.77	12,000 ±471

4. Conclusion

Method of selective beta ray detection using the sensitivity difference between thick and thin plastic scintillation was suggested. The ability of discrimination between beta-ray and gamma-ray was tested and successfully proven. Subsequent application to low-radioactive sources and additional evaluation of energy-dependent gamma-ray sensitivity should be performed.

REFERENCES

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