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Background Spectrum Simulation for In-situ Measurement Technology

Byungchae Lee [a*], Seunggi Jeong [a], Jihyun Yu [a], Jonghoa Kim [a], Jangsoo Suh [a], Sangbum Hong [b]
[a] *R&D Institute, Sae-An Enertech Corp, 65 Techno 3-ro, Yuseong-gu, Daejeon, 34016, Korea*
[b]*Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Daejeon, 34057, Korea*
[*]*Corresponding author: bclee@sae-tec.com*

1. Introduction

In general, In-situ measurement technology uses a shield to minimize the impact of the environment. However, due to the weight of the shield, movement constraint, worker fatigue, and falls may occur. Therefore, it is necessary to develop In-situ measurement technology that minimizes environmental impact and improves mobility[1-3]. In this research, the background spectrum was simulated to reduce measurement uncertainty of the Peak to Compton (PTC) method, which is an In-situ measurement technology developed in previous research[4,5]. The background spectrum was simulated with MCNP for the energy of 34 gamma rays emitted from natural nuclides. The simulated spectrum was evaluated compared to the spectrum measured in a general environment. If the results of this research and the PTC method are applied to contaminated site, it can be used as a useful technology for quickly and accurately evaluating radioactivity.

2. Methods

In order to reduce the measurement uncertainty of the PTC method, which is an In-situ measurement technology, it is necessary to accurately grasp the background spectrum of the Compton continuum area. The background spectrum of the Compton continuum area of ^{137}Cs, a nuclide mainly emitted from the contaminated site, was simulated by MCNP. The Compton continuum area of ^{137}Cs ranges from 381.38 to 410.29 keV. Among the gamma rays emitted from natural nuclides, the intensity was 1 % or more, and the energy spectra of 34 gamma rays affecting the ^{137}Cs Compton continuum area were simulated (Table 1). The geometry was assumed to be measured at a distance of 50 cm with a Potable High Purity Germanium (Canberra, GC4019) detector, and the effective area of measurement was set to 1,000 cm x 1,000 cm. In addition, natural nuclides were assumed to be homogeneous at all depths, and the spectrum of the ^{137}Cs Compton continuum area was simulated using F8 tally. The Compton continuum area was calculated using the ratio of the Full energy peak of the spectrum simulating each gamma ray energy to the measured Full energy peak. The simulated background spectrum was compared with 39 spectra (28 in Daejeon and 11 in Jeju) measured in an uncontaminated environment as shown in Fig. 1 to evaluate the accuracy.

Table 1. Gamma energy and intensity of natural nuclides

Nuclide	Energy (keV)	Intensity (%)	Nuclide	Energy (keV)	Intensity (%)
^{228}Ac	463.0	4.4	^{214}Bi	1155.2	1.6
^{7}Be	477.6	10.3	^{214}Bi	1238.1	5.8
^{208}Tl	511.0	22.6	^{214}Bi	1281.1	1.4
^{208}Tl	583.0	84.5	^{214}Bi	1377.7	4.0
^{214}Bi	609.3	46.1	^{214}Bi	1408.0	2.2
^{212}Bi	727.2	7.6	^{40}K	1460.8	11.0
^{214}Bi	768.4	4.9	^{214}Bi	1509.2	2.1
^{212}Bi	785.5	1.3	^{212}Bi	1620.6	1.5
^{228}Ac	794.7	4.3	^{228}Ac	1630.4	1.5
^{214}Bi	806.2	1.2	^{214}Bi	1661.3	1.2
^{56}Mn	846.8	98.9	^{214}Bi	1729.6	2.9
^{208}Tl	860.6	12.0	^{214}Bi	1764.5	15.4
^{228}Ac	911.1	25.8	^{214}Bi	1847.4	2.1
^{214}Bi	934.1	3.0	^{214}Bi	2118.6	1.1
^{228}Ac	964.4	5.0	^{214}Bi	2204.2	5.1
^{228}Ac	969.1	15.8	^{214}Bi	2447.9	1.6
^{214}Bi	1120.3	15.1	^{208}Tl	2614.7	99.0

Fig. 1. In-situ gamma-ray spectroscopy for measurement of natural nuclides at sites.

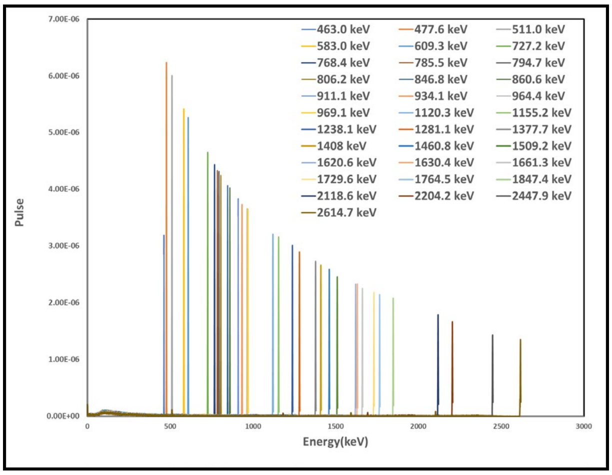

Fig. 2. Gamma spectra of natural nuclides calculated by MCNP simulation

Table 2. Comparison of In-situ measurement results and MCNP simulation results in ^{137}Cs Compton continuum area

No	Measurement (CPS)	MCNP (Pulse)	Relative error (%)	No	Measurement (CPS)	MCNP (Pulse)	Relative error (%)
1	4.62	4.55	1.49	21	4.07	4.07	0.01
2	4.60	4.55	4.08	22	4.25	4.24	0.09
3	4.01	3.89	3.05	23	4.17	4.17	0.01
4	4.02	3.95	1.84	24	4.22	4.16	1.39
5	3.99	3.83	3.86	25	4.33	4.33	0.01
6	4.18	4.26	1.92	26	4.35	4.35	0.10
7	4.11	4.18	1.95	27	4.35	4.35	0.01
8	4.19	4.33	3.18	28	4.43	4.31	2.62
9	4.23	4.19	0.94	29	1.27	1.25	1.78
10	4.13	4.23	2.43	30	1.26	1.28	1.69
11	4.02	4.13	2.74	31	1.31	1.31	0.01
12	4.13	4.24	2.61	32	1.12	1.14	1.57
13	4.16	4.30	3.27	33	1.16	1.16	0.01
14	4.45	4.45	0.04	34	1.15	1.15	0.01
15	4.55	4.54	0.16	35	1.30	1.32	1.79
16	4.41	4.59	3.90	36	1.35	1.29	4.04
17	4.59	4.81	4.77	37	1.31	1.34	2.62
18	4.41	4.61	4.46	38	1.33	1.32	1.28
19	4.54	4.54	0.01	39	1.32	1.32	0.01
20	4.22	4.22	0.01				

3. Results

In order to reduce the measurement uncertainty of the PTC method, the background spectrum was simulated and evaluated by comparison with the measured spectrum. The spectrum simulated for each gamma energy is shown in Fig. 2. The results of the Compton continuum area of the measured and simulated spectrum are shown in Table 2. As a result of comparing the spectra measured in Daejeon (No. 1 to 28) and Jeju (No. 29 to 39), it was found that Jeju showed lower radioactivity. In the case of Jeju, it is judged that the radioactivity is low because the proportion of natural nuclides contained in the soil is lower than that of other regions. As a result of comparing the measured spectrum and the simulated spectrum, it was found that the relative error was 0.01 % to 4.81 %, showing high accuracy. The reason for the high accuracy is considered to be because the Full energy peak ratio of the measured and simulated spectrum for each gamma ray energy was calculated.

4. Conclusions

In order to reduce the measurement uncertainty of the Peak to Compton method, an In-situ measurement technology, the background spectrum of the ^{137}Cs Compton continuum area was simulated with MCNP. As a result of comparing the simulated background spectrum with the spectrum measured in an uncontaminated environment, the average relative error was within 5 %. It is expected that this evaluation method will be able to quickly and accurately evaluate radioactivity if it is applied to the decommissioning site of a nuclear power plant or a site contaminated by an accident in the future. Additional research on metal and concrete is needed to apply the evaluation method of this study to various environments.

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