Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Activation Characteristics for Concrete Shielding Wall of KRR-2 : verification of technology using in-situ measurement

Jihyun Yu*, Byungchae Lee, Seunggi Jeong , Jonghoa Kim , Jangsoo Suh, , Sangbum Hong [b]
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: vdnj5308@sae-tec.com*

1. Introduction

This is concrete waste, which accounts for most of the radioactive waste produced during decommissioning. And this is the most important factor determining the economic feasibility of NPP decommissioning projects. Contaminated concrete is a type of concrete waste that can reduce the amount of waste by physical decontamination. However, to reduce the amount of waste generated by radioactive concrete, it is important to accurately identify and categorize radionuclides, radioactivity levels, and radioactivity distribution.

In general, the radiological characteristics of radioactive concrete are performed by laboratory analysis through concrete sampling. But it cannot be evaluated by this method in environmental conditions where regulation and application are not possible. Therefore, it is difficult to apply operation monitoring or decommissioning plan steps. So, it is necessary to secure in-situ measurement technology that can be applied to all environments.

In this study, the applicability of KRR-2 was evaluated based on the evaluation algorithm derived from the Peak to Compton (PTC) method of in-situ measurement technology. And the results were compared with KAERI, which has core technology, to verify the validity of the technology.

2. Methods

2.1. Characteristics of activation concrete by the depth

Through case reports of decommissioning of KRR-2 and Trojan nuclear power plant, it was confirmed that the increased the thickness of the concrete, the exponential decrease. In this case, the distribution of radioactivity can be expressed as follows.

$$A(\zeta)=A_0 e^{-\frac{\zeta}{\beta}} = A_0 e^{-\frac{\rho x}{\beta}} \qquad (1)$$

Where ζ is the effective mass per unit area, A_o is the specific activity of the surface, the depth of contamination, and ρ is the density of the soil. Based on this type of activation, the evaluation algorithm was derived by applying the PTC method.

2.2. Peak to Compton method

The gamma rays cause the photoelectric and Compton effects by interacting with the medium. At this time, if the thickness of the medium is increased, the energy of gamma rays is absorbed by the medium. Therefore, the count rate of the full energy peak is reduced. On the other hand, the probability of scattering increases. Therefore, the count rate of the Compton continuum area increases.

The PTC method analyzes the distribution of radioactive by depth using the ratio(Q-value) of the Compton continuum count rate to the full energy peak count rate by the change in thickness of the medium. This method should be evaluated with minimal impact on natural radionuclides because of its low accuracy due to the nature of field measurements. To do this, after removing the BKG spectrum from the measured spectrum, the ratio to the net counting rate of each region is calculated.

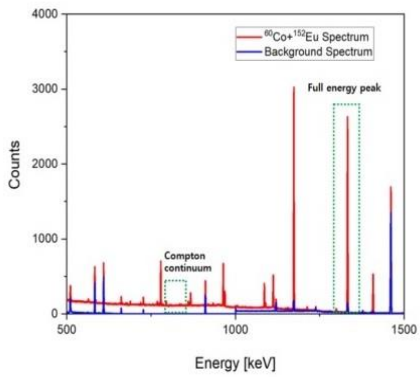

Fig. 1. Peak to Compton method for radioactivity depth distribution.

$$Q=\frac{Net\ full\ energy\ peak\ counting\ rate}{Net\ compton\ continuum\ counting\ rate} \qquad (2)$$

2.3. Evaluation of field applicability

The feasibility of core technology for NPP decommissioning was evaluated by performing field application tests on the concrete structure of KRR-2. Currently, the KRR has completed the decommissioning of the reactor core & major facilities, and concrete structures were also decontaminated and demolished.

However, the field application test was conducted because it was meaningful in terms of application to nuclear facilities. In-situ measurements were conducted at many concrete facilities in KRR-2 (general, reactor floor, basement, etc.). The detector used for the measurement is a mobile HPGe detector (GC-3018, Canberra) with an energy resolution of 1.8 keV (at 1,332 keV) and relative efficiency of 30 %. Considering that most concrete structures are environmental radiation levels, measurements were made without shielding, and because there are multiple measurement points, the in-situ measurement was performed for 3600 seconds for each measurement point.

Fig. 2. In-situ measurement of concrete structures in KRR-2.

First, the detected radionuclides and count rates at each measurement point were analyzed based on the measured gamma spectrum. And the work was first performed to confirm the detected points of ^{60}Co and ^{152}Eu, which are representative gamma radionuclides of radioactive concrete. Then, after removing the background spectrum from the measured spectrum, the Q-value for the counting rate in the peak area per counting rate in the Compton continuum area was calculated. Finally, the activation for the concrete shielding wall was derived by substituting the Q-value into the evaluation algorithm. Additionally, the field application test was conducted under the same conditions (measurement period, measurement point, measurement method, etc.) as KAERI, and was qualitatively verified based on the analysis results.

3. Results

As a result of spectrum analysis, it was confirmed that ^{60}Co and ^{152}Eu, which are representative gamma radionuclides of radioactive concrete, were detected only on the Reactor floor of the KRR-2. However, ^{60}Co was detected in the steel of the concrete shielding, it was also detected that ^{60}Co was too high for ^{152}Eu in the spectrum. Therefore, only ^{152} Eu was evaluated. As a result of calculating the Q-value by applying the PTC method, SAE-AN was 0.48 and KAERI was 0.21. The reason why Q-values are different under the same conditions during in-site measurement is that the geometric shape and detection efficiency of the detector used is different. Then, as a result of substituting it into the evaluation algorithm, it was found that the activation(β) was 30.18 and 33.60, respectively. Based on the β value the relative error of each institution was 5.67% and the analysis results of the two institutions showed a highly consistent.

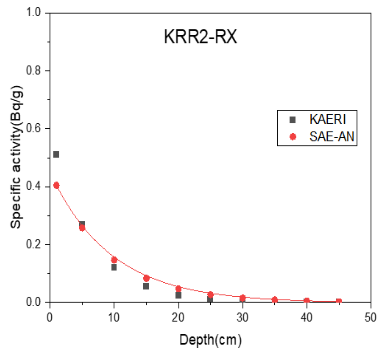

Fig. 3. Comparison of the activation of SAE-AN & KAERI for KRR-2

In Figure 4, the concrete before removal corresponds to the surface portion of the exponential model, and this part has the highest radioactivity. However, the removed concrete corresponds to the flat slope of the exponential model. Therefore, it is difficult to identify the difference in radioactivity by depth. The evaluation algorithm is derived based on the correlation between the total depth from the surface to the inside.

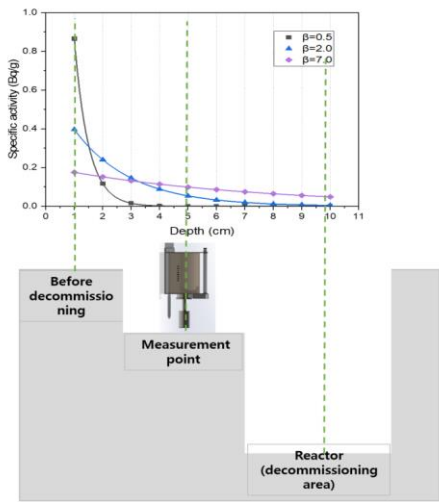

Fig. 4. Evaluation of activation of decontaminated and decommissioning for concrete shielding wall

However, in the case of KRR-2, the β value should be interpreted as the level of residual activity because part of the activation for concrete has already been removed. Therefore, it has been confirmed that there are limitations to the application of this technology in the case of removing the activation for concrete shielding. Despite these limitations, the reliability of the technology was evaluated by substituting the concrete density of KRR-2 and the β value derived from each organization with equation (1). The results showed that 40.5 % (SAE-AN) and 37.6 % (KAERI) of the level of residual activity were distributed at a depth of 1 cm. In addition, 66.3 % (SAE-AN) and 62.7 % (KAERI) of the level of residual radioactivity were distributed at a depth of 5 cm and showed that 81.0 % (SAE-AN) and 77.8 % (KAERI) were distributed at a depth of 10 cm. The average relative error for the radioactivity distribution by depth was about 3.4 %, indicating that the analysis results of the two institutions were highly consistent.

4. Conclusions

This study is meaningful in verifying the reliability of evaluation algorithms (based on the PTC method) through Field Application Tests of KRR-2. As a result of the analysis, the relative error with KAERI (core technology) was 5.67 %. Activation from KRR-2 concrete could not be evaluated at depth. But, to verify the reliability of the PTC method, we calculated the probability of radioactivity distribution by depth for the level of residual radioactivity. As a result, the error between the two institutions was less than 3.4%, confirming a highly consistent. In addition, it was confirmed that the validity of the PTC method was demonstrated to evaluate the activation of concrete shielding walls. In the future, it will be necessary to carry out research on reliability verification based on the results of quantitative analysis by providing a chance for laboratory analysis after sampling.

REFERENCES

[1] B. C. Lee, Gamma-Ray Spectrometry to Find the Distribution of Diffused Radioactive Sources Underground, New Physics: Sae Mulli, Vol. 69, No. 7, July 2019, pp. 701-706.

[2] Hong, S.B.; Kang, M.J, Lee, K.W.; Chung, U.S, "Development of scaling factors for the activated concrete of the KRR-2." Appl. Radiat. Isot. 67, 2009, pp.1530-1533.

[3] S.B. Hong, J.S. Nam, Y.S. Choi, B.K. Seo, J.K. Moon, Application of In Situ Measurement for Site Remediation and Final Status Survey of Decommissioning KRR Site, Journal of Radiation Protection and Research 41(2), 2016.

[4] Korea Atomic Energy Research Institute (KAERI), KAERI Report No. KAREI/RR-4525/2019, 2019.

[5] Fujibuchi, T.; Nohtomi, A.; Baba, S.; Sasaki, M.; Komiya, I.; Umedzu, Y.; Honda, H, "Distribution of residual long-lived radioactivity in the inner concrete walls of a compact medical cyclotron vault room." Ann. Nucl. Med. 29, 2015, pp.84-90.

[6] B.C. Lee, S.B. Hong, B.K. Seo, J.H. Kim, Y.U. Kim, In situ measurement of Cs distribution in the soil, New Physics. 69(7), pp. 701-706, 2019.

[7] B.C. Lee, Y.U. Kim, W.S. L'yi, J.H. Kim, B.K. Seo, S.B. Hong, Radiological analysis for radioactivity depth distribution in activated concrete using gamma-ray spectrometry, Applied Radiation and Isotopes 169, 2021.