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Evaluation of the internal dose of dismantling workers for bio-shield of Kori NPP unit 1

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1. Introduction

As part of the project to develop bio-shield dismantling technology for Kori NPP unit 1, the internal dose of Kori NPP unit 1 dismantling worker was evaluated. Because the bio-shield is large, it takes a long time to dismantle, which increases exposure to workers. Therefore, the dose that would be received by workers should be assessed before dismantling. To assess internal dose for the worker, the radioactivity of the bio-shield was first evaluated using the Monte-Carlo code MCNP. Based on the evaluation results, the dismantling scenarios using DWS were considered and then the internal exposure was evaluated.

2. Methods and Results

In this section some of the techniques used to evaluate internal dose of worker during dismantling are described. The evaluation includes a radioactivity analysis, scenario analysis. Two methods for evaluating dose is used for internal dose assessment.

2.1 Radioactivity analysis

The MCNP code was used to evaluate the response of the neutron flux to each part of the simulated bio-shield geometry. It is possible to evaluate the reactions between the bio-shield and neutrons generated by the reactor over a long period of time using MCNP code. Five nuclides (^{60}Co, ^{152}Eu, ^{154}Eu, ^{3}H, ^{55}Fe) in the Kori NPP unit 1 bio-shield were analyzed using MCNP6 [1]. Calculated radioactivity is shown at table 1.

Table I: Radionuclide distribution in bio-shield (Bq/g)

nuclide	Internal zone (300~410 cm)	External zone (410~520 cm)
^{60}Co	1.46E+03	3.05E-02
^{152}Eu	4.56E+00	9.56E-05
^{154}Eu	1.46E+03	3.06E-02
^{3}H	3.21E+04	6.72E-01
^{55}Fe	7.90E+02	1.65E-02

As a result of the radiative evaluation, the closer to the core, the higher the radioactivity, and tritium has the highest the radioactivity.

2.2 Scenario analysis

For concrete cutting, Diamond Wire Saw (DWS) cutting method is assumed. Considering the cutting speed of DWS [2], the time required to cut the bio-shield was derived. The distribution of dust generated during cutting refers to the general distribution of aggregate in various processes [3].

Two dose assessment methods were used to evaluate the internal exposure dose. First, the dust generated during cutting was divided by the volume of the working space. The formula for this dose evaluation is shown in Equation 1 below [4].

$$\mathrm{H_i} = \mathrm{D_i} B \mathrm{C_i} t f \frac{V_1}{V_2} \tag{1}$$

$\mathrm{H_i}$ = Inhalation dose of i isotope (mSv)
$\mathrm{D_i}$ = Dose coefficient i isotope(mSv/Bq)
B = Breathing rate($\mathrm{m^3/h}$)
V_1 = Voloume of damaged concrete($\mathrm{m^3}$)
V_2 = Voloume of working space($\mathrm{m^3}$)
$\mathrm{C_i}$ = Concentration of i isotope($\mathrm{Bq/m^3}$)
f = Inhalation ratio
t = working time(h)

In this scenario, the worker will work with all the dust generated during the work being released into the air. Therefore, it is expected that the maximum internal dose to the worker during dismantling.

The second method considers consecutive ventilation during dismatling and considers removal of dust due to ventilation. This method is a more realistic method because it considers ventilation unlike the previous method. The formula for this dose evaluation is shown in Equation 2 and 3 below [5].

$$\mathrm{H_i} = \mathrm{D_i} B \mathrm{C_i} R f t \tag{2}$$

$$R = \frac{pS}{V_2 E} \tag{3}$$

p = Dust production rate at cutting kerf (m)
S = Cutting speed ($\mathrm{m^2/h}$)
E = Air exchange rate ($\mathrm{h^{-1}}$)

2.3 comparison results of two methods

Table 2 shows the results of the dose evaluation using two methods.

As a result of the dose evaluation, the dose of ^{60}Co was the highest, followed by ^{152}Eu, ^{154}Eu, ^{3}H and ^{55}Fe. In the case of tritium, the radiative value was high, but the dose coefficient was lower than other nuclides.

Also, method 2 was evaluated to be 100,000 times lower than method 1. This result shows that ventilation is important for internal exposure reduction. For the doses assessed in method 1, the internal exposure dose at ^{60}Co was rated significantly higher than the worker annual dose limit of 50 mSv recommended by ICRP. It requires workers to take safety measures such as wearing a mask. However, if ventilation is considered as method 2, the dose will be assessed as 1.75E-02 mSv. According to the results of this assessment, bio-shield dismantling does not require any special protective measures.

Table Ⅱ: Inhalation dose comparison of two methods for inhalation exposure assessment (mSv)

	Method 1	Method 2
^{60}Co	1.10E+03	1.72E-02
^{152}Eu	1.52E+01	2.38E-04
^{154}Eu	6.72E-01	1.05E-05
^{3}H	5.66E-03	8.83E-08
^{55}Fe	5.49E-07	8.56E-12
Sum	1.12E+03	1.75E-02

Using the same method, the ingestion dose during bio-shield disassembly is calculated and shown in Table 3.

Table Ⅲ: Ingestion dose comparison of two methods for inhalation exposure assessment

	Method 1	Method 2
^{60}Co	4.94E+01	7.66E-04
^{152}Eu	1.20E-02	1.12E-07
^{154}Eu	2.55E-04	2.44E-09
^{3}H	0.00E+00	0.00E+00
^{55}Fe	5.73E-08	8.91E-13
Sum	4.95E+01	7.66E-04

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In the case of ingestion during normal operation, some dust accompanies the inhalation as it moves to the gastrointestinal tract.

As a result, the dose was 22 times lower than the dose. As with the inhalation dose, Method 1 was highly evaluated compared to Method 2, and the total dose in Method 1 was 49.5 mSv.

3. Conclusions

In order to evaluate the radiological safety of the bio-shield dismantling worker, the worker's internal dose by the dust generated during the dismantling work was evaluated. In order to evaluate the internal dose, two methods are considered to evaluate internal dose. The method 1 in which the maximum dose appeared, and the method 2 in which the ventilation was considered. As a result, the dose was very low considering ventilation with comparing results of method 1 and 2.

Based on these results, we can analyze the effects of various factors related to internal exposure and can establish and optimize protection measures for worker safety.

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