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Comparison of Radiation Dose Rates with the Flux to Dose Conversion Factors Recommended in ICRP-74 and ICRP-116

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1. Introduction

The evaluation of radiation shielding has been performed for the design and maintenance of various facilities using radioactive sources such as nuclear fuel, accelerator, and radionuclide. Meanwhile, the radiation dose rates for a shielding analysis are evaluated by applying dose conversion factors to radiation flux. The conversion of flux to dose mainly used in nuclear and radiation fields has been generally made with the dose coefficients presented in ICRP Publication 74 (ICRP-74) [1], which are produced based on ICRP Publication 60.

On the other hand, ICRP Publication 116 (ICRP-116) [2], which adopts the protection system of ICRP Publication 103, has recently been published and provides the dose conversion coefficients calculated with a variety of Monte Carlo codes. The coefficients have more than an update of those in ICRP-74, including new particle types and a greatly expanded energy range.

In this study, a shielding evaluation of a specific container for neutron and gamma sources was performed with the MCNP6 code [3]. The flux to dose conversion factors produced based on ICRP-74 and ICRP-116 were applied and the resultant radiation dose rates were quantitatively analyzed from a series of calculations.

2. Methods and Results

2.1 Flux to Dose Conversion factors

In practical radiation shielding, the compliance of the protection quantities such as effective dose rates are required below certain levels to assure the legal dose limits. Conversion coefficients provide relationships between flux and effective doses in radiation transport analysis. With the insurance of ICRP-74, the flux to dose conversion factors have been used for a variety of radiation shielding analysis.

Meanwhile, ICRP-116 has derived new sets of dose conversion coefficients in conjunction with up-to-date Monte Carlo radiation transport codes. Main changes include expanding the particle types and energy ranges as follows;

- neutron: 0.001 eV – 10 GeV,
- photon: 10 keV – 10 GeV,
- electron/positron: 50 keV – 10 GeV, and
- proton: 1 MeV – 10 GeV.

Figure 1 and **2** show the flux to dose conversion factors in ICRP-74 and ICRP-116.

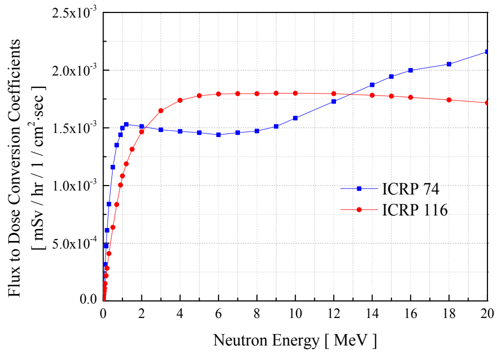

Fig. 1. Flux to Dose Conversion Coefficients for Neutron

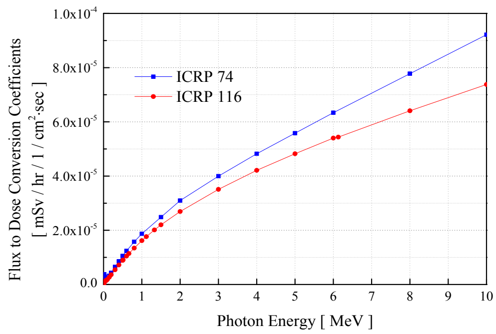

Fig. 2. Flux to Dose Conversion Coefficients for Gamma-ray

2.2 Specifications of Shielding Model and Sources

A specific conceptual model of a shielding container was assumed to compare the radiation dose rates applied with the existing and new conversion factors. The diameter and the height of the container are 51cm and 60cm, respectively, with a thickness of 0.5cm. The materials for radiation shielding are lead with stainless steel, and the detailed information on the calculation model is shown in **Figure 3**.

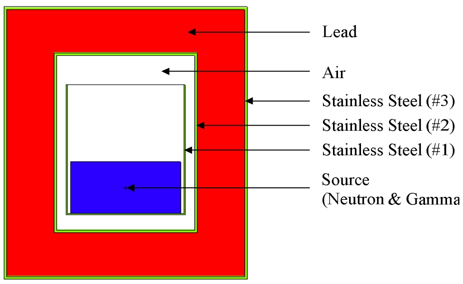

Fig. 3. A Calculation Model for Analyzing the Effect of Flux to Dose Conversion Factors

Some radioactive materials including TRU nuclides were assumed to be generated from the spent fuel, and these calculations were performed using the ORIGEN-S module in the SCALE6.1 package code system [4]. **Figure 4** and **5** show the calculated neutron and gamma spectra of which energy ranges are divided into 44 and 18 groups, respectively.

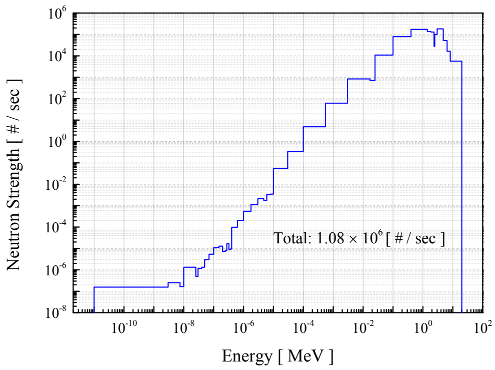

Fig. 4. Neutron Spectrum (44 groups)

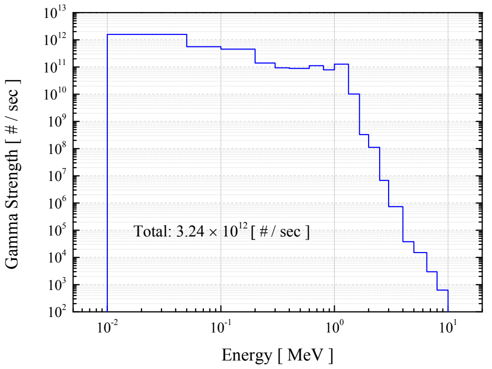

Fig. 5. Gamma Spectrum (18 groups)

3. Results and Discussions

Figure 6-8 present the radiation dose rates at the side of the container, which is divided into 20 segments for the height of its internal cavity (SS #2). The relative errors are below 1% in all of the MCNP results. As shown in the figures, the maximum value in the entire result is indicated at the height of about 8cm which is a center of the radiation source. The trends of these results are similar with each other, and the dose rates with ICRP-74 conversion factors are generally higher than the other.

The maximum dose rates for each source are tabulated in the **Table 1**. In comparison of the results with different dose conversion factors, the differences for gamma-rays (including secondary gamma-ray) and neutrons show approximately 14% and 25%, respectively.

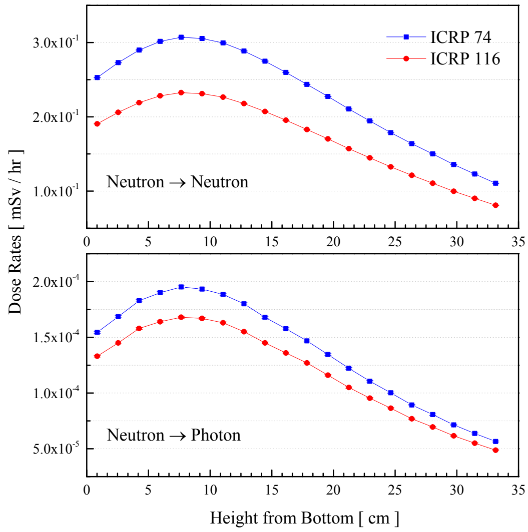

Fig. 6. Dose Rate Distributions from Neutron Source

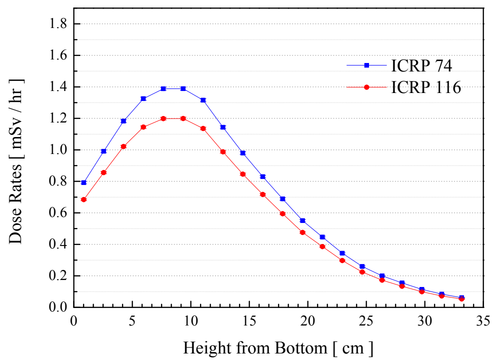

Fig. 7. Dose Rate Distributions from Gamma-ray Source

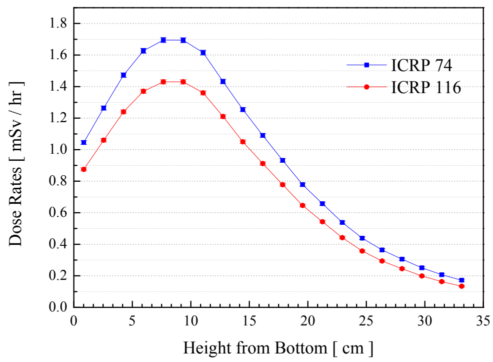

Fig. 8. Total Dose Rate Distributions

Table 1. Maximum Dose Rates and Differences

Source		Dose Rates [mSv/hr]		Difference [%]
		ICRP-74	ICRP-116	
Neutron	p	1.95E-04	1.68E-04	13.70
	n	3.07E-01	2.33E-01	24.25
Photon		1.39E+00	1.20E+00	13.65
Total		1.69E+00	1.43E+00	15.57

3. Conclusions

The dose rates from neutron and gamma-ray sources were calculated using the MCNP6 codes, and these results were based on the flux to dose conversion factors recommended in ICRP-74 and ICRP-116. As a result, the dose rates evaluated with ICRP-74 were generally shown higher than those with ICRP-116. For neutrons, the difference is mainly occurred by the decrease of radiation weighting factors in a part of energy ranges in the ICRP-116 recommendations. For gamma-rays, the ICRP-74 recommendation applied with the kerma approximation leads to overestimated results than the other assessment.

This result can be referred for the effect of these conversion factors in shielding analysis, but it needs to perform additional studies in other energy ranges widely used in nuclear fields.

REFERENCES

[1] ICRP, Conversion Coefficients for Use in Radiological Protection against External Radiation, International Commission on Radiological Protection (ICRP) Publication 74, Pergamon Press, 1996.
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