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Study of Radiation Shielding Analysis for Low-Intermediate Level Waste Transport Ship

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1. Introduction

In Korea, it is planed to transport Low-Intermediate Level Radioactive Waste (LILW) from each nuclear power plant site to Kyongju LILW repository after 2009. Transport through the sea using ship is one of the most prospective ways of LILW transport for current situation in Korea. There are domestic and international regulations for radiation dose limit for radioactive material transport [1,2,3,4]. In this article, radiation shielding analysis for LILW transport ship is performed using 3-D computer simulation code, MCNP [5]. As a result, the thickness and materials for radiation shielding walls next to cargo in the LILW transport ship are determined.

2. Regulations

In the domestic and international laws related to nuclear waste transport, there are several regulations about it. Focused on the objective of this article, the related regulations about radiation dose rate limit for LILW is in Table 1. All areas in the transport ship except cargo area are categorized as living area, so its dose rate limit is 1.8 μSv/h, and dose rate in the cargo area or surface of the ship is limited to 2,000 μSv/h. Also the dose rate at any point 2m away from the ship is limited to 0.1 μSv/h.

Category		Dose rate limit [μSv/h]
Area	Cargo area	N/A (2,000†)
	Working area	7.5
	Living area	1.8
Distance	Surface of ship	2,000
	2m away from ship	0.1

Table 1. Radiation dose rate limit
(† It is assumed that the dose rate limit for cargo area is the same as one of surface of ship.)

3. Calculations and Results

In this section method to calculation and conditions required to perform a calculation are described.

3.1 Method to analysis

Before performing MCNP calculation, followings are required to get a result: geometry of a transport ship, material properties of structures, radiation source, and detector positions. And because of long calculation time of MCNP for shielding calculation, preliminary thicknesses of shielding walls obtained by QADS code are used as starting values for MCNP calculation. QADS needs much shorter calculation time by using deterministic method instead of Monte Carlo method used by MCNP code. After MCNP calculations with trial-and-error way, the minimum thicknesses of radiation shielding walls satisfying the regulation limit can be obtained and these are the objectives of the calculation.

3.2 Geometry and material

The schematic geometry of transport ship for MCNP calculation is in Fig.1. There are 4 cargos in the ship, and each cargo can carry up to 200 transport containers (IP-2 type). Each transport container contains 8 waste drums and dose rate limit of drum for transport is determined in a preceding calculation based on dose rate limit of a transport container.

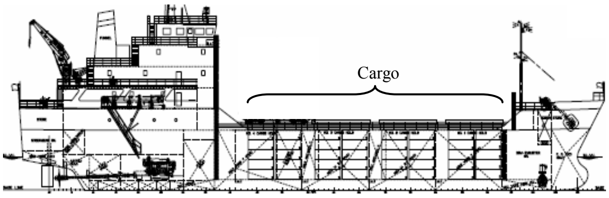

Figure 1. Geometry of LILW Transport Ship

All metals used in the calculation are assumed to be carbon steel, SS400, and concrete as shielding material is assumed to be Orconcrete9. The hyper-pressed repackaging waste is used as a waste material, and its radiation dose rate is used as a source term for calculation. The compositions of these materials are in Table 2.

Material	Density [g/cm^3]	Composition [wt%]
SS400	7.85	Fe(98.00) Mn(1.03) C(0.30) Cu(0.30) Si(0.28) S(0.05) Pt(0.04)
Orconcrete9	2.30	O(41.02) Ca(32.13) C(17.52) Si(3.45) Mg(3.27) Al(1.08) Fe(0.78) H(0.62) K(0.11) Na(0.03)
Waste material	0.25	C(57.48) Cl(20.43) H(8.52) O(7.58) F(4.49) N(1.52)

Table 2. Composition of materials for calculation

3.3 Source

The average radioactivity for each categorized isotope in LILW generated from domestic nuclear reactors is referred in this article. Among many elements from the above data, several radioisotopes yield radioactivity, but for the conservatism, it is assumed that there is only Co-60 isotope in the radioactive waste and it is used as a whole radiation source in the calculation. Co-60 is a gamma source which produces two different energy levels of gamma ray that are 1.17MeV, 50% and 1.33MeV, 50%. With preceding calculation using MCNP for source term in the LILW and accompanying with the dose rate limit for a transport container, the acceptable dose rate value per drum for transport is acquired. This acceptable dose rate value per drum for transport is the criteria for determining which drum can be transported by container (IP-2 type) or not. In this calculation, the acceptable dose rate value per drum for transport is 1.1204E9 photon/sec when the thickness of the transport container panel is assumed to be 15mm.

3.4 Detector positions

In this MCNP calculation, virtual detectors (i.e. F5 tally) are placed at considering points to obtain the information about dose rate. Several detectors are placed near the surface of the ship, living area for crews, wheel house deck and etc. These detectors are placed usually on the center line of the ship since the dose rate could be the largest in it. These virtual detectors in MCNP calculation simulate the real detectors in the transport ship in the real situation. The counting values from virtual detectors are the value expected from the calculation.

3.5 Results

The calculation results are summarized in Table 3. It shows the minimum thicknesses of the shielding walls within the regulatory limit of dose rate.

Detected place			Minimum thickness [mm]		
			SS400 (Head)	Orconcrete9	SS400 (Tail)
Tail	L	M	6	320	6
		S	6	200	6
	U	M	6	100	6
		S	0	0	15
Head	L	M	6	350	6
		S	6	250	6
	U	M	6	10	6

Table 3. Minimum thickness of shielding walls
(L=Lower deck, U=Upper deck, M=Middle, S=Side)

4. Conclusion

Radiation shielding analysis using MCNP code shows the minimum thicknesses of the shielding walls in the transport ship. However, many conservatisms and assumptions are considered in the calculation, the calculated minimum thickness could be much thicker than required one in the real. For the safety and economical efficiency, further calculation with less assumption and accurate radiation source term could help reduce the risk from the improper assumptions or the cost due to uselessly thicker shielding walls.

REFERENCES

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