Monte Carlo Calculation of "Shadow Shielding Effect" of Arrayed Casks

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Casks are widely used for transportation and storage of nuclear spent fuel and radioactive waste. Generally, a cask has a thick shielding wall as a part of the containment, which attenuates radiation from the contained radioactive source to keep the radiation dose rate as low as regulations require. However, the surface of the cask still emits radiation and may become a larger source if many casks are gathered together. Such a condition may occur in a cask transport ship or a temporary storage area on the transport route. A shadow shielding effect can exist among arrayed casks. The effect could become significant at a distance from the casks due to the air-scattered radiation from all casks. The effect could resolve a site boundary dose rate issue if it is verified quantitatively. However, the radiation dose rate of many casks is currently evaluated by summing up the individual contribution without considering this shadow effect. We have examined reasonable estimation of the environmental dose rate considering the shadow shielding effect by a Monte Carlo technique. We started the calculation from a small number of casks in an array (4 and 9) and then expanded the calculation to about 100 or more. In the analysis, arrayed cylindrical casks are modeled in a three-dimensional geometry. We have utilized the three-dimensional and continuous energy Monte Carlo code MCNP-4B. Moreover, a variance reduction technique is applied to a deep-penetration calculation of a thick shielding wall of a cask. The analysis has verified that the decrease of dose rate (direct radiation and skyshine) by the shadow effect amounts to about 50% for neutrons and 60% for gamma rays in some cases. The reduction of dose rate by the effect is considerable and can be considered as one countermeasure to implement a reasonable environmental dose rate calculation for a large number of casks.