Comparison of the Transportation Risks Resulting from Accidents during the Transportation of the Spent Fuel

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1. Introduction

The safe, environmentally sound and publicly acceptable disposal of high level wastes and spent fuels is becoming a very important issue. The operational safety assessment of a repository including a transportation safety assessment is a fundamental part in order to achieve this goal. According to the long term management strategy for spent fuels in Korea, they will be transported from the spent fuel pools in each nuclear power plant to the central interim storage facility (CISF) which is to start operation in 2016. Therefore, we have to determine the safe and economical logistics for the transportation of these spent fuels by considering their transportation risks and costs. In this study, we developed four transportation scenarios by considering the type of transportation casks and transport means in order to suggest safe and economical transportation logistics for spent fuels. Also, we estimated and compared the transportation risks resulting from the accidents during the transportation of spent fuels for these four transportation scenarios.

2. Modeling and Assumptions

We considered two types of transportation casks during the development of the transportation scenarios. One is the existing TN international concept, the TN24-XLH capable of carrying 24 spent fuel assemblies, and the other is the KN-12 cask capable of carrying 12 spent fuel assemblies.

We assumed that the casks will be transported by ship because the four nuclear power plant sites are located by the sea. We considered two types of ships during the development of the transportation scenarios, the INF2 and INF3 ships. They are certified to carry irradiated nuclear fuel and high-level radioactive wastes. The INF3 ships have an advantage in that they can carry packages with an unlimited amount of activity, but they are very expensive. Among the four nuclear power plant sites, we considered the YongGwang (YG) site. If we assume that the first phase of the transport between the YG site and CISF will start in 2016, and it will last 25 years, 472 fuel assemblies will transported per year.

The four transportation scenarios by considering the capacity of the casks and the ships are as follows; 1) 4 maritime journeys with 5 TN24-XLH onboard the INF2 ship, 2) 1 maritime journey with 20 TN24-XLH onboard the INF3 ship, 3) 4 maritime journeys with 10 KN-12 onboard the INF2 ship, 4) 1 maritime journey with 40 KN-12 onboard the INF3 ship.

The source terms for the estimation of a health effect risk during the transportation of a spent fuel are summarized in Table 1. They were estimated for the 17x17 Vantage 5H fuel assemblies by using the ORIGEN-ARP. We assumed that the discharge burn-ups were 45 GWD/MTU and the cooling times were 7 years.

We considered three accidents, that is, a collision, a fire, and a foundering and sinking. The accident probabilities are 6.22×10^{-7} accidents/km for a collision, 6.59×10^{-8} accidents/km for a fire, and 4.78×10^{-7} accidents/km for a foundering and sinking[1]. The transportation distance was assumed to be 650 km. The risks were estimated by using the RADTRAN5 developed by Sandia National Laboratory [2]. Other parameters that enter the calculational process, such as release fraction, shielding factors, deposition velocity, aerosol fraction, respirable fraction were derived from the DOE Handbook on Transportation Risk Assessment[3].

3. Results and Discussion

Risks for the spent fuel transportation arise from both conventional vehicular accidents and exposures to a ionizing radiation under both normal and accident conditions. Transportation risk includes health and safety risks that arise from the exposures of workers and members of the public to a radiation from shipments of wastes[4]. The health effect risks arise from exposures of people who travel, work, or live near transportation routes and transportation workers themselves to a radiation from radioactive waste packages. In this study, we consider only the population risk resulting from the radioactive materials released to the atmosphere

According to the results summarized in Table 2, the expected values for the population risk in person-Sv are in the range of 1.89×10^{-7} and 3.29×10^{-7} for the collision accident, 2.00×10^{-8} and 5.71×10^{-8} for the fire accident, 1.45×10^{-7} and 4.14×10^{-7} for the foundering and sinking accident. All these values of the population risks in person-Sv are low radiological risk activities with a manageable safety and health consequence. Among the four scenarios, the scenario using the KN-12 cask and the INF2 ship reveals the largest value for the population risk in person-Sv due to the small capacity of the cask and the many maritime journeys.

Table 1. Source Terms for a sample spent fuel (Ci).

Radionuclide	Inventory	Radionuclide	Inventory
H-3	2.65E+02	Ba-137m	4.99E+04
Mn-54	3.43E-03	Ce-141	1.45E-18
Fe-55	7.24E-01	Ce-144	1.06E+03
Co-58	1.80E-01	Pr-144	1.06E+03
Co-60	2.59E+01	Pr-144m	1.49E+01
Kr-85	3.18E+03	Pm-147	1.28E+04
Sr-89	2.10E-10	Pm-148m	2.98E-15
Sr-90	3.66E+04	Sm-151	2.15E+02
Y-90	3.66E+04	Eu-154	2.40E+03
Y-91	3.30E-08	Eu-155	5.97E+02
Zr-95	6.47E-07	U-232	1.62E-02
Nb-95	1.43E-06	U-233	1.70E-05
Ru-103	1.79E-14	U-234	5.20E-01
Rh-103m	1.79E-14	U-235	7.48E-03
Rh-106	2.44E+03	U-236	1.51E-01
Rh-106m	0.00E+00	U-238	1.33E-01
Ru-106	2.44E+03	Pu-238	2.07E+03
Sn-123	3.03E-04	Pu-239	1.61E+02
Sb-125	7.28E+02	Pu-240	2.60E+02
Te-125m	1.78E+02	Pu-241	5.34E+04
Te-127	5.80E-04	Am-241	7.91E+02
Te-129	2.18E-19	Am-242m	5.39E+00
Te-129m	3.41E-19	Cm-242	5.02E+00
I-129	1.84E-02	Am-243	1.72E+01
Cs-134	5.29E+04	Cm-244	1.98E+03
Cs-137	5.29E+04		

Table 2. Expected Values of Population Risk (Person-Sv)

Accident Scenario	Collision	Fire	Foundering and Sinking
1	3.29E-07	3.48E-08	2.53E-07
2	1.89E-07	2.00E-08	1.45E-07
3	5.39E-07	5.71E-08	4.14E-07
4	1.89E-07	2.00E-08	1.45E-07

4. Conclusion

We estimated and compared the transportation risks resulting from accidents during the transportation of spent fuels from the YongGwang site to the central interim storage facility (CISF) which were assumed to be located near the Wolsong nuclear power plant site. We developed four transportation scenarios by considering the type of transportation casks and transport means. We found that these four transportation scenarios for spent fuels have a very low radiological risk activity with a manageable safety and health consequence. The results of this study can be used as basic data for the development of safe and economical logistics for a transportation of the spent fuels in Korea by considering the transportation costs for the four scenarios which will be made in the near future.

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