Estimation Radioactivity of Reference Spent Fuel With Time and Total Radioactivity of All Spent Fuel at 2035

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1. Introduction

According to Public Engagement Commission on Spent Nuclear Fuel Management (PECOS) recommendation report, present spent fuel pools of nuclear power plant in Korea will be saturated by the middle of 2020, constructions of independent spent fuel dry storage facilities are expecting. On July 25, 2016, the Korea government announced “the basic plan for high-level radioactive waste management” based on the recommendation of PECOS. The roadmap was established based on this plan, and the roadmap includes that the Korea government will select the disposal site by 2028, complete the construction of interim storage facilities by 2035, and complete the construction of the permanent disposal facility by 2053 [1]. In order to achieve the goal, the spent fuel to be generated in future should be accurately estimated and more detailed analysis of spent fuel is requested.

The object of this study was to estimate radioactivity of reference spent fuel with time and total radioactivity of all spent fuel at 2035.

2. Materials and Methods

2.1 Spent fuel databases and applied codes

In this study, pressurized water reactors (PWRs) spent fuel data until 2015 provided from Korea Hydro and Nuclear Power (KHNP) was used. It includes fuel number, initial enrichment, mass of initial uranium, discharge burnup, and Final cycle fuel withdrawal date. According to this database, 5,549 assemblies of spent fuel were stored in Kori and Shin-Kori nuclear site, 5,693, 4,847, and 129 assemblies was stored in Hanbit, Hanul, and Shin-Wolsong nuclear site respectively.

To estimate radioactivity of reference spent fuel with time and total radioactivity of all spent fuel at 2035, Automatic Multi-batch Origen Runner for Evaluation of Spent fuel (AMORES) was used. This code was developed by the cooperation between KINS and Kyung Hee University and it can automatically generate ORIGEN-S input files and process their output files.

2.2 Estimation of radioactivity of reference spent fuel

The reference PWR spent fuel was determined based on PWRs spent fuel databases. The spent fuel with initial enrichment of 4.5wt% of ^{235}U, discharge burnup of 45,000 MWd/MTU, and mass of initial uranium of 440,000 g was adopted for reference spent fuel. For this reference spent fuel, individual nuclide radioactivity was calculated for spent fuel taken out of the reactor 1, 10, 20, 30, 40 years using AMORES.

2.3 Estimation of total radioactivity of all spent fuel

To estimate total radioactivity of all spent fuel at 2035, amount of spent fuel generated between 2016 and 2034 was estimated based on the national 7th electric power supply schedule [2]. The Eq. (1) was used to calculate the annual generation of the spent fuel,

$$Amount_{SF} = \frac{NC \cdot 365.25 \cdot CF}{\epsilon_{th} \cdot BU} \qquad (1)$$

where NC is the NPP capacity, CF is the capacity factor, ϵ_{th} is the NPP efficiency, and BU is the average discharge burnup of the spent fuels. Also, we didn’t considered life extension of NPP except for Kori unit 1. For Kori unit 1, we considered life extension for 10 years.

Based on PWRs spent fuel database until 2015 and estimated amount from 2016 to 2034, individual nuclide radioactivity was calculated using AOMRES. To do this, 99 target nuclides were considered. The selected nuclides included all the actinides from thorium to californium and important fission product.

3. Results and Discussion

3.1 Results of radioactivity for reference spent fuel

Radioactivity of reference spent fuel were 1.10 × 10^{17} Bq/MTU, 2.01 × 10^{16} Bq/MTU, 1.44 × 10^{16} be numbered separately. Fig.1 show the composition of radioactivity of reference spent fuel for each times. Radioactivity of 1 year old spent fuel were mainly contributed from ^{144}Pr and ^{144}Ce, while the others were mainly contributed from ^{137}Cs, ^{241}Pu, and ^{90}Sr. This can be explained by difference of the half-life of each nuclides. ^{144}Pr ($T_{1/2}$=17.3 m), ^{144}Ce ($T_{1/2}$=285 d) have relatively short half-life, it can only affect in early time. The results of this study were similar to results of Korea Atomic Energy Research Institute [3].

3.2 Results of radioactivity for all spent fuel.

The amount of PWR spent fuel until 2015 in Korea was about 6,800 MTU, and accumulated amount of spent fuels form 2016 to 2034 was about 10,000 MTU. Based on these data, radioactivity for all spent fuel at 2035 was estimated (Table 1). Total radioactivity at 2035 was 2.26 × 10^{16} Bq/MTU, which was similar to 10 years old representative spent fuel radioactivity. ^{137}Cs occupied the biggest radioactivity (30%), and followed by ^{241}Pu (25%), ^{90}Sr (21%), ^{106}Ru (6.6%). These composition was similar to 10 years old representative spent fuel except ^{106}Ru. In 10 years old representative spent fuel, ^{106}Ru wasn't considered major nuclide, but in case of total radioactivity at 2035, ^{106}Ru was considered to be the major nuclide with more 1% ratio.

Table 1. Radioactivity of all spent fuel at 2035

Nuclide	Radioactivity of all spent fuel (Bq/MTU)			
	by 2015 y	2016~2034 y	Total	Ratio
^{137}Cs	2.38E+15	4.31E+15	6.69E+15	30%
^{241}Pu	1.40E+15	4.22E+15	5.62E+15	25%
^{90}Sr	1.63E+15	3.07E+15	4.71E+15	21%
^{106}Ru	3.60E+09	1.50E+15	1.50E+15	6.6%
^{147}Pm	8.20E+12	1.43E+15	1.43E+15	6.3%
^{134}Cs	1.73E+12	1.19E+15	1.19E+15	5.2%
^{85}Kr	6.87E+13	2.84E+14	3.53E+14	1.6%
^{238}Pu	1.05E+14	1.55E+14	2.60E+14	1.1%
^{241}Am	1.44E+14	7.94E+13	2.24E+14	1.0%
^{154}Eu	3.02E+13	1.78E+14	2.08E+14	0.9%
Other	1.10E+14	3.63E+14	4.73E+14	2.1%
Total	5.88E+15	1.68E+16	2.26E+16	100%

4. Conclusion

In this study radioactivity of reference spent fuel and total radioactivity of all spent fuel at 2035 was estimated using AMORES. Radioactivity of reference spent fuel decreased from 1.10 × 10^{17} Bq/MTU to 3.70 × 10^{15} Bq/MTU over time and radioactivity of all spent fuel at 2035 was 2.26 × 10^{16} Bq/MTU. The results of this study can be used as input for interim storage facility.

REFERENCES

[1] Ministry of Trade, Industry and Energy, "the basic plan for high-level radioactive waste management" (2016).

[2] Ministry of Trade, Industry and Energy, "7th electric power supply schedule" (2015).

[3] KAERI, "Reference spent fuel and its characteristic for the concept development of a deep geological disposal system" (1997).

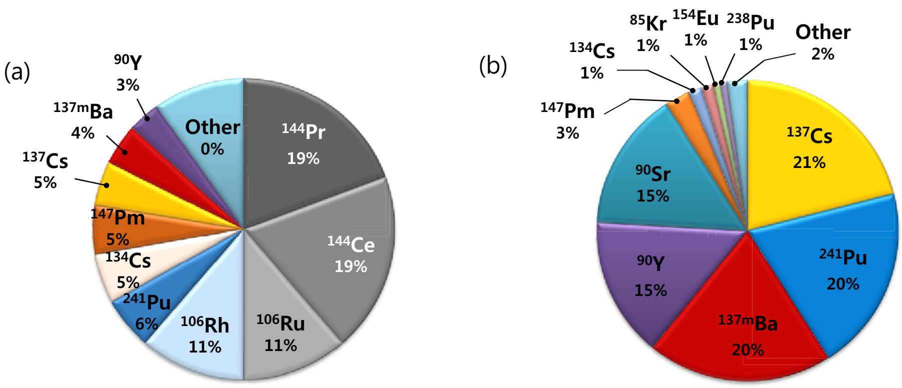

Fig. 1. Composition of radioactivity of reference spent fuel for (a) 1 year, (b) 10 years since removal from reactor.