Evaluation on Characteristics of Wastes from Pyro-processing of CANDU SNFs based on CANDU FS v5.1

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1. Introduction

To reuse valuable fissile materials in SNFs and reduce volume and toxicity of SNFs, KAERI has been developing P&T technology based on pyro-processing and SFR. In this technology, only PWR SNFs are considered because of low fissile content and high purity of plutonium of CANDU SNFs. Low fissile content reduces economic profit of pyro-processing of CANDU SNFs. And recovery of TRU containing high purity plutonium with lack of economic benefits could cause misunderstanding and declination of the credibility on non-proliferation. However, demand on quantitative analyses of influence of pyro-processing of CANDU SNFs is magnified because extremely huge amounts of SNFs have been generated from the four CANDU NPPs. To evaluate influence of adopting P&T of CANDU SNFs, characteristics of wastes from pyro-processing of CANDU SNFs are evaluated based on CANDU FS v5.1 which is developed for CANDU SNFs in 2018.

2. Methods and Results

2.1 Assumptions and Methods

To evaluate characteristics of wastes from pyro-processing of CANDU SNFs, reference fuel described below is considered and Origen-arp in SCALE6.1 program is used.

- Reference fuel type: CANDU 37
- Enrichment: 0.711 wt.% (natural uranium)
- Discharge burn-up: 8,100 MWd/MtU
- Specific power: 23.668 MW/MtU
- Cooling time before pyro-processing: 10 years

Material balance for CANDU SNFs had been developed in 2018 based on FSv5.1 of PWR SNFs. The brief information about wastes and products from pyro-processing of 30 tons of CANDU SNFs based on CANDU FSv5.1 is listed in Table 1. Eight types of wastes and two types of products are generated from pyro-processing of CANDU SNFs. The REE Waste and the Metal Waste are contaminated by TRU element. The Tc-Filter Waste and the I-Filter Waste are containing long-lived I-129, Tc-99 which are highly mobile in repository environment. Also, the Metal Waste is contaminated by large amounts of Tc. The Tc-Filter, the Sr Waste, and the Metal Waste are containing Se-79 that is major contributor to activity release and dose evaluation results. The C/H Waste is containing C-14 that is another major contributor of dose evaluation results.

Table 1. Wastes and Products from pyro-processing of CANDU SNFs based on FSv5.1 (basis: 30 tons) [1]

	Nuclide mass [kg]	Total mass [kg]	Major Nuclides
Metal Waste	2.11E+02	4.35E+03	U, Zr, Mo, Ru, Pd, Rh, Tc, Sn
Tc-Filter Waste	4.25E+00	5.55E+01	Tc, Se, Mo, Sb, Te
I-Filter Waste	1.96E+00	6.17E+01	I, Br
C/H Waste	2.73E+00	2.83E+02	H-3, C-14
Kr/Xe	4.39E+01		Kr, Xe
Cs-Filter Waste	2.19E+01	4.12E+02	Cs, Rb, Cd, Ag
Sr Waste	2.68E+01	3.76E+02	Sr, Ba, Sm, Eu, Sb, Te
REE Waste	3.76E+01	9.00E+01	RE, TRU
U Ingot	2.95E+04		U
U/TRU Ingot	1.89E+02		U/TRU, MA, RE

2.2 Results

Figure 1-3 show evaluated decay heat, radioactivity, and radiotoxicity of outputs from pyro-processing of CANDU SNFs based on CANDU FSv5.1 respectively. Until several hundred years, most of decay heat, radioactivity, and radiotoxicity are generated from the Sr Waste and the Cs-Filter Waste. After that, the U/TRU Ingot generates most of decay heat, radioactivity, and radiotoxicity. Therefore, decay heat, radioactivity, and radiotoxicity after 200 years can be reduced by complete reuse of U/TRU Ingot. Also, heat load of repository can be decreased by long-term storage of the Cs-Filter and the Sr Waste.

Table 2 shows decay heat, radioactivity, radiotoxicity of wastes and products at disposal time. Total cooling time before the disposal is 30 years. More than 99% of decay heat, radioactivity, radiotoxicity are generated from the Cs-Filter Waste, Sr Waste, U/TRU Ingot.

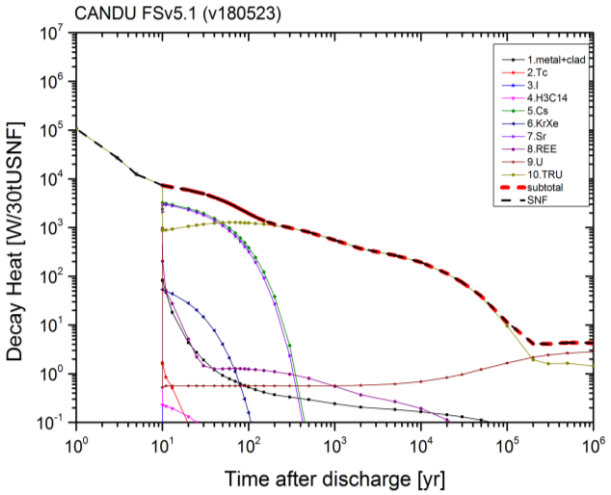

Figure 1. Decay heat of wastes and products from pyro-processing of CANDU SNFs based on FS v5.1

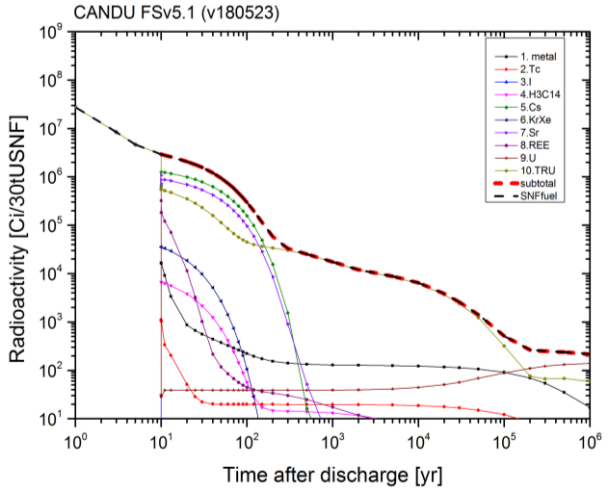

Figure 2. Radioactivity of wastes and products from pyro-processing of CANDU SNFs based on FS v5.1

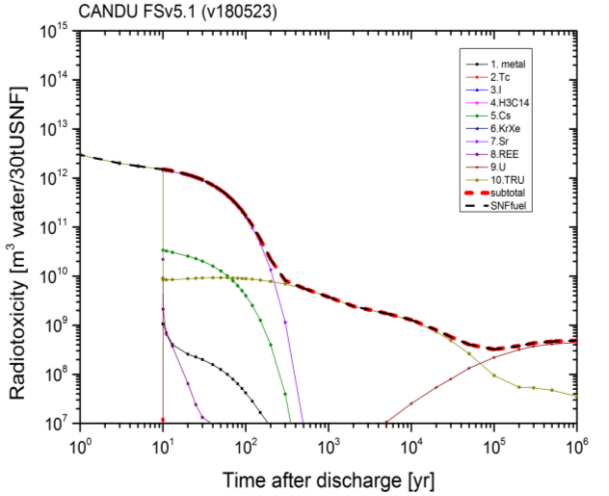

Figure 3. Radiotoxicity of wastes and products from pyro-processing of CANDU SNFs based on FS v5.1

Table 2. Decay heat, radioactivity, radiotoxicity of Wastes and Products at the disposal time (basis: 30 tons)

(basis: 30 ton)	Decay heat		radioactivity		radiotoxicity	
	[W/30 MtU]	[%]	[Ci/30 MtU]	[%]	[m^3 water /30 MtU]	[%]
Metal Waste	1.91E+00	0.04%	5.60E+02	0.04%	1.99E+08	0.02%
Tc-Filter Waste	1.60E-02	0.00%	2.23E+01	0.00%	1.29E+06	0.00%
I-Filter Waste	1.18E-04	0.00%	2.53E-01	0.00%	4.22E+06	0.00%
C/H Waste	7.73E-02	0.00%	2.18E+03	0.00%	7.40E+05	0.00%
Kr/Xe	1.95E+03	39.51%	7.86E+05	39.51%	2.02E+10	2.20%
Cs-Filter Waste	1.46E+01	0.30%	9.74E+03	0.30%	9.74E+03	0.00%
Sr Waste	1.80E+03	36.46%	5.38E+05	36.46%	8.90E+11	96.77%
REE Waste	1.46E+00	0.03%	1.03E+03	0.03%	1.32E+07	0.00%
U Ingot	5.64E-01	0.01%	3.89E+01	0.01%	1.05E+06	0.00%
U/TRU Ingot	1.17E+03	23.64%	2.32E+05	23.64%	9.14E+09	0.99%
SNFfuel	4.94E+03	100.00%	1.57E+06	100.00%	9.20E+11	100.00%

3. Conclusions

Characteristics of wastes and products from pyro-processing of CANDU SNFs based on CANDU FSv5.1 are evaluated in this study. More than 99 % of decay heat, radioactivity, and radiotoxicity are generated from the Cs-Filter Waste, Sr Waste, U/TRU Ingot at disposal time. With complete reuse of U/TRU in SFR and long-term storage of the Cs-Filter Waste and the Sr Waste, heat load of repository could be considerably reduced. Characteristics of CANDU pyro-wastes identified in this study will be used to design disposal system for comparison of direct disposal scenario and closed fuel cycle scenario of CANDU SNFs.

CANDU SNFs can be disposed of in fairly small area compared to PWR SNFs due to very low decay heat, radioactivity, and radiotoxicity of CANDU SNFs. Decay heat, radioactivity, radiotoxicity of CANDU SNFs is 1/7, 1/5, and 1/9 of PWR SNFs respectively at disposal time. Therefore, large reduction of decay heat, radioactivity, and radiotoxicity of wastes from pyro-processing cannot be directly connected to large reduction of disposal area. Also, effect of introduction of subsidiary facilities for pyro-processing and SFR reactors must be considered for comparison between direct disposal case and P&T case.

REFERENCES

[1] Hun Suk Im, et. al., Flowsheet for Pyroprocessing Facility with 30tHM/year capacity (CANDU FS v.5.1), KAERI, 2018