Comparison analysis of dose of operating worker for spent resin mixture treatment facility with single and double line systems

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1. Introduction

The spent resin generated from the heavy-water reactor should be treated to reduce the radioactivity concentration of ^{14}C in it to meet low-level radioactive waste disposal criteria. However, the spent resin is stored in the storage tank because of their relatively high radioactivity concentration, which belongs to intermediate-level radioactive waste, and properties [1-3]. Due to the powdering and hardening phenomenon of the spent resin, storing the spent resin for a long period is considered as a problem of the nuclear industry [4-5]. The treatment facility that can separate the mixture (zeolite, activated carbon and resin) and the spent resin treatment technology using microwave has been developed. Microwave of this facility can treat the resin without generation of secondary waste. The facility is divided into two parts of spent resin mixture separation and spent resin treatment, where each part consists of double-line system for redundancy. In this study, comparison analysis of exposure dose of operating worker between single-line and double-line systems of the facility was performed. Only external dose was considered in dose analysis except for internal dose because the worker operates the facility in the remote-operation room.

2. Methods and Results

2.1 Source term of spent resin mixture

The source term was derived from the sampling of spent resin mixture from the resin storage tank #2 of Wolseong nuclear power plant and analysis of HPGe gamma spectrometer. Sampling was performed by dividing the storage tank into three points according to the height considering the hardening and gradient phenomenon of spent resin mixture. The maximum values of the sampled spent resin mixture were considered to analyze conservative exposure dose. Radioactivity concentration of mixture are represented in Table I. The materials (zeolite, activated carbon, and spent resin) of the spent resin mixture do not have all radionuclides, and as shown in Table I, each has some specific radionuclides. Each line can contain 500 kg of spent resin mixture. Therefore, it was assumed that single-line system has 500 kg of spent resin mixture and double-line system has 1,000 kg of spent resin mixture.

Table I: Source term of spent resin mixture (Bq/g)

Radion uclides	Zeolite	Activated carbon	Spent resin
^{57}Co	-	-	2.91E+01
^{60}Co	9.37E+01	1.85E+02	4.94E+02
^{51}Cr	-	-	2.58E+02
^{134}Cs	6.60E+01	2.47E+00	1.57E+01
^{137}Cs	9.11E+04	2.45E+03	1.72E+04
^{54}Mn	-	-	2.67E+01
^{95}Nb	8.68E-01	7.31E+00	4.39E+01
^{125}Sb	-	1.55E+01	4.25E+02
^{95}Zr	-	-	2.75E+01
^{152}Eu	-	-	5.12E+02
^{154}Eu	-	-	4.33E+01
^{3}H	8.55E+03	1.56E+04	3.30E+04
^{14}C	1.98E+02	2.22E+03	1.54E+05

2.2 3D-modeling of the treatment facility

The source term values are used as input parameters of external dose analysis using VISIPLAN code. This code can generate 3D radiation environment and evaluate the external exposure dose of worker according to the working scenarios. In this study, the 3D-modeling of single-line and double-line systems of the facility were conducted to compare the exposure doses between them of remote-operating worker in the remote-operation room which is located 5 m away from the facility. It was assumed that the worker is in the middle of the remote-operation room for operation of the facility. The figure 1 represents the 3D-modeling of the facility.

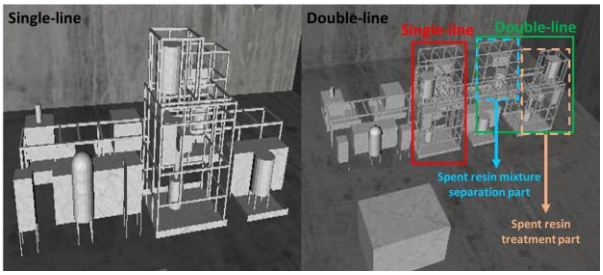

Fig. 1. 3D modeling of the single-line and double-line of the facility.

2.3 Comparison analysis of exposure dose between single-line and double-line systems of the facility

As shown in Table II, external dose of remote-operating worker based on the operation time

(preparation of treatment for 1 hr, operation for 5 hrs, and after operation for 1 hr) and the number of lines (single-line and double-line systems) was estimated to compare the radiological safety in the case of operation of the facility.

Table II: External dose rate of remote-operating worker according to the number of line of the facility (mSv/h)

Time	Single-line	Double-line
Preparation of treatment	6.83E-04	1.36E-03
1 hr	5.95E-04	1.23E-03
2 hr	6.46E-04	1.33E-03
3 hr	8.12E-04	1.42E-03
4 hr	8.67E-04	1.38E-03
5 hr	1.08E-03	1.64E-03
After operation	1.46E-03	1.97E-03
Total	6.14E-03	1.03E-02
Annual dose (mSv)	1.54E+00	2.58E+00

The working time for 1 day was assumed to be 7 hrs. The daily doses for single-line and double-line were derived as 6.14E-03 mSv and 1.03E-02 mSv respectively. The difference between each dose was 4.19E-03 mSv when there were 500 kg and 1,000 kg of spent resin mixture inside the facility. The dose of the worker was derived differently because the spent resin moves within the facility as the operating time elapsed. In 'After operation', the highest dose was derived because spent resin was concentrated in the spent resin storage tank and 200 L drum located relatively close to the remote-operation room. The double-line is also relatively far away from the remote-operation room. In addition, due to the geometry of the facility, worker has some shielding and is less radiologically affected. ^{137}Cs, ^{60}Co, and ^{152}Eu have the impact on worker's dose at 97.7 % (83.8 % for ^{137}Cs, 8.78 % for ^{60}Co, and 5.15 % for ^{152}Eu, respectively). Annual doses (50 weeks per year, 5 days per week, 7 hours per day) of single-line and double-line were derived as 1.53E+00 mSv and 2.58E+00 mSv which are 7.65 % and 12.9 % of the average annual dose limit (20 mSv) of worker. Therefore, the radiological safety of worker could be confirmed regardless of single-line and double-line of the facility.

3. Conclusions

In this study, the exposure dose comparison analysis was conducted based on the number of line and operation time of the facility. The source term from the sampling of the spent resin mixture and modeling information were considered in dose analysis. Although there is 1,000 kg of spent resin mixture in the double-line of the facility, the annual exposure dose of worker was lower than the average annual dose limit. Therefore, it was confirmed that the radiological safety could be secured in the case of operation of the facility.

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