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Developing the Technology for Using the Microwave to Remove C-14 from the Spent Resin from HWR Nuclear Power Plants

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1. Introduction

Spent resin is generated a year 124,560L from HWR nuclear power plants. As of December 2017, 622,800L is in storage. For a verification experiment of the HWR spent resin mixture, 20L of sample was collected from tank #2 in Wolsong 1 two times. We developed a device for using the microwave to treat the HWR spent resin mixture, and conducted the verification experiment.

This study intended to develop the treatment technology for disposal of the HWR spent resin mixture. The spent resin was separated from the mixture (active carbon, zeolite and spent resin) in Room No. S-147 of Wolsong 1 for 3 months. The microwave was used to remove the C-14 nuclide in the separated spent resin, and to verify the possibility of using the adsorbent to recycle C-14, the HWR spent resin mixture treatment verification experiment was conducted.

2. Experimental method

2.1 Establishing the verification experiment plan and procedure

We selected the NPP for the HWR spent resin mixture treatment verification experiment, gave an on-site presentation, and conducted the verification experiment according to the verification experiment plan and procedure.

In this study, we used the actual spent resin collected from Room No. S-147 of Wolsong 1 to separate the mixture, and conducted the HWR spent resin mixture treatment verification experiment by desorbing and adsorbing C-14.

2.2 HWR spent resin mixture treatment process

The spent resin mixture in the spent resin storage tank consists of active carbon, zeolite and spent resin. As the spent resin has a high concentration of the long-lived nuclide C-14, only the spent resin must be separated and treated. The spent resin mixture treatment process is as follows:

1) Feed the spent resin mixture (Zeolite, Active carbon and Spent resin)
2) Separate the spent resin mixture according to particle sizes
3) Disposing the separated active carbon and zeolite mixture
4) Feed the separated spent resin into the microwave reactor
5) Use the microwave to desorb the C-14 in the spent resin
6) Use the adsorption tower to adsorb C-14 (Primary circulation)
7) Compress the residual C-14 with the gas storage tank to adsorb C-14 (Secondary circulation)
8) Dispose of the post-reaction resin as Very Low-Level Waste (VLLW)

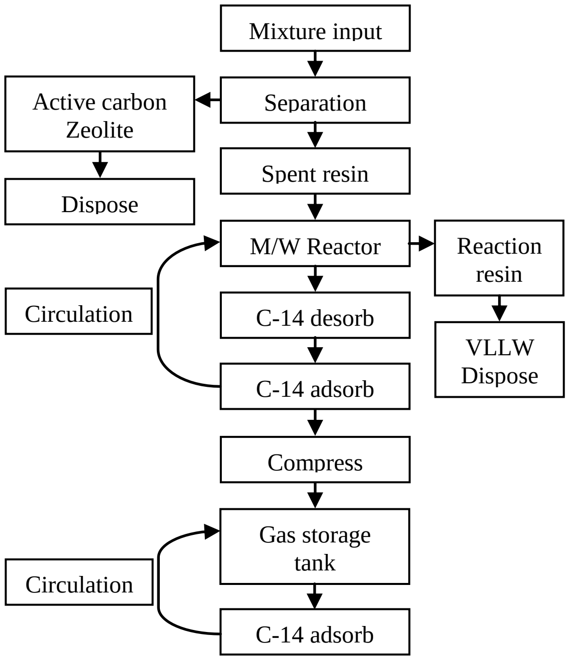

Fig 1. HWR spent resin mixture treatment process map

2.3 Start-up test of the device and performance test

To test the performance of the HWR spent resin mixture treatment device, we used a simulated sample (zeolite, active carbon and resin) to conduct the start-up test. Theoretically, as for the storage condition of the spent resin mixture, the active carbon and zeolite mixture is 20%, and the spent resin is 80%. Considering this condition, we fed the active carbon and zeolite mixture of the simulated sample 26%, and the resin 74%, and conducted the start-up test for the mixture separation performance test for 2 minutes. As a result, more than 95% of the mixture was separated.

We conducted the resin transfer performance test to remove the C-14 in the spent resin separated from the spent resin mixture. The result confirmed that 700g of waste flowed in consistently along with the spent resin during the transfer. Considering the moisture content (45~55%) of the resin and the design capacity (1kg of dry resin) of the microwave reactor, it can be known that the optimal transfer time is 1 minute.

Table 1. Mixture separation performance test

Sample	Input	Separation time	Recovery quantity	Separation factor
Active carbon + Zeolite	756 g	2 min	720 g	95 %
Resin	2,010 g		2,046 g	
Active carbon + Zeolite	768 g	2 min	737 g	96 %
Resin	1,999 g		2,030 g	
Active carbon + Zeolite	734 g	2 min	698 g	95 %
Resin	2,005 g		2,041 g	

Table 1. Separated resin transfer quantity performance test

Sample	Input	Transfer time	Transfer quantity	Waste transfer quantity
Resin	2,987 g	1 min	1,426 g	700 g
Resin	2,717 g	1 min	1,222 g	700 g
Resin	2,067 g	1 min	788 g	700 g
Resin	2,158 g	1 min	941 g	700 g

Table 3. Microwave operating time according to resin status

Sample	Input	Generating power	Operating time (min)	Sample state
Resin	2 kg	100 %	0 – 30	Wet
Resin	2 kg	100 %	30 – 60	Dry
Resin	2 kg	100 %	60 – 90	Dry Carbonization

To check the status if the resin depending on the operating time of the microwave, we conducted the start-up test. As nuclear power plants dispose of spent resin when it is dry, the spent resin must be kept dry after reaction using the microwave. Also, to check whether the C-14 in the spent resin can be recycled, the generation of C-12 from the carbonization of the spent resin must be minimized. Considering this condition, it can be known that the optimal microwave operating time ranges between 30 minutes and 60 minutes.

2.4 Verification experiment

2.4.1 Target samples

The samples used for the HWR spent resin mixture treatment verification experiment were collected from tank #2 of Wolsong 1 at the manhole and the inspection port two times. The samples used for the verification experiment were 15L of the manhole sample, and 2L of the inspection port sample.

2.4.2 Operating conditions

Based on the results of the device start-up test and the performance test, the actual spent resin mixture treatment verification experiment was conducted. To check the desorption and adsorption of C-14 in the spent resin by using the microwave for direct heating, we varied the internal temperature of the microwave reactor for each batch, and Table 4 shows the operating conditions for each batch.

Table 4. Spent resin mixture treatment operating conditions

Classification	Target sample	Input of mixture	Input of reactor
BATCH 1	Manhole	7 L	2 kg
BATCH 2	Manhole	4 L	2 kg
BATCH 3	Manhole	4 L	2 kg
BATCH 4	Test hole	2 L	2 kg
Classification	**Operating conditions**		**Quantity of samples emitted after reaction**
BATCH 1	- 100% generating power - 100℃ 30min maintenance		976 g
BATCH 2	- 100% generating power - 130℃ 30min maintenance		1,324 g
BATCH 3	- 100% generating power - 140℃ 30min maintenance		967 g
BATCH 4	- 100% generating power - 140℃ 3 min maintenance		722 g
Average quantity of samples emitted after reaction			997.25 g

3. Results

To treat the spent resin mixture, we used the samples collected from tank #2 of Wolsong 1 to conduct the verification experiment for the HWR spent resin mixture treatment process. The operating conditions of the experiment consist of 4 batches. We used the optimal conditions, derived from the start-up test for the mixture separation and transfer process. Also, we used the optimal conditions, derived from the start-up test, for the time it takes to use the microwave to treat the C-14 in the spent resin. To analyze the desorption of C-14 for each batch, we used the direct-method on-site Liquid Scintillation Counter(LSC). The result shows that 94.4% of the C-14 was desorbed on average.

Table 5. Analysis of C-14 using the direct method

Sample	C-14 (DPM)	C-14 Desorption efficiency
A0 (Manhole)	5,892,028	-
BATCH 1	351,127	94 %
BATCH 2	220,432	95 %
BATCH 3	282,607	96 %
A0 (Test hole)	5,281,270	-
BATCH 4	395,040	92.5 %
Average desorption efficiency		94..4 %

4. Conclusion

To dispose of the spent resin mixture of HWR nuclear power plants, we need to develop the technology for separating the active carbon and zeolite mixture, and removing the radioactive nuclide from the spent resin, which is mid-level waste, so that it goes below the low level or the very low level, and trapping and treating the removed radioactive nuclide in a chemically stable way to reduce the disposal volume. Also, we need to review the validity of recovering and recycling C-14, which is an expensive resource, instead of disposing of it. This study separated more than 95% of the active carbon and zeolite mixture from the mixture (active carbon, zeolite, spent resin) using the spent resin mixture samples collected from tank #2 of Wolsong 1, and established various operating conditions for individual batches to derive the condition for desorbing and adsorbing the C-14 in the actual spent resin.

But as it is difficult to investigate the correct desorption and adsorption of C-14 using the direct-method on-site Liquid Scintillation Counter (LSC) analysis alone, we asked the Korea Atomic Energy Research Institute to correctly analyze C-14 desorption and adsorption.

5. Acknowledgments

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6. REFERENCES

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