Evaluation of Treatment Efficiency of Boron Containing Discharge Water Using CDI&SD-ELIX with Serial Arrangement

[1]Seonggeon Kim, [1]Seongjoo Kang, [1]Sangwook Lee, [1]Jiyang So, [1]Ducheol Kim, [1]Minho Kwak,
[1]Seungil Kim*
[1]Elim-Global Co. Ltd., 767, Sinsu-ro, Suji-gu, Yongin-si, Gyeonggi-do, Republic of Korea.
*seungil.kim@elim-global.com

1. Introduction

Unlike overseas nuclear power plants, domestic nuclear power plants operate within a small area due to restrictions on the site of the nuclear power plant. Even if there is a trace amount of material that can affect the environment, the possibility of being released simultaneously due to multiple exhalation operations cannot be ruled out. Not only radioactive substances but also ionic substances such as boron can be released, so it should be minimized as much as possible.

In the case of operating a waste evaporator in the liquid radwaste system (LRS), the boron concentration in the monitor tank, which stores the waste liquid before discharge, can be kept low below 10 ppm. However, in new nuclear power plants that use ion exchange resin and reverse osmosis membrane for liquid waste treatment systems, it is difficult to remove boron in liquid waste because it exists in the form of boric acid. Since regulations on boron discharge from wastewater are becoming stricter worldwide, separate facilities to selectively remove boron are essential. This research attempted to treat boron containing discharged water using CDI (Capacitive deionization) and SD-ELIX (Specifically designed-electrochemical exchange) with serial modules.

2. Methods

2.1 Single Module (1000L) Circulation Test

Assuming that the concentration in the tank is lowered by circulating treated water by installing a separate boron removal facility in the monitor tank of the nuclear power plant, a circulation test was conducted to understand the boron removal characteristics of the electrochemical boron removal facility. Using CDI facility, 1000L of ultrapure water having an electrical conductivity of 5 μS/cm or less was produced, and boron was mixed to prepare boric acid water having a concentration of about 55 mg/L, and used in the test. The prepared boric acid water was separated from boron by operating the SD-ELIX equipment for about 300 minutes. The effluent water and the electrolyte water of SD-ELIX were circulated to the influent water of SD-ELIX, and the concentrated water was collected in a separate tank.

In order to confirm that the boron concentration decreases, the boron concentration was analyzed by collecting samples of influent water, effluent water, and concentrated water at 5, 10, 30, 60, 120, 180, 240, and 300 minutes.

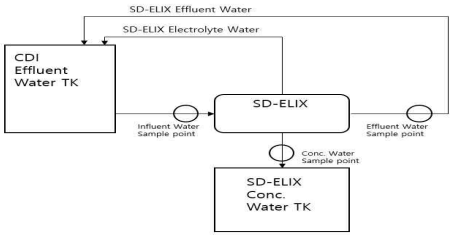

Figure 1. Single Module (1000L) Recycle Test Mimetic diagram

2.2 Serial Module (2500L) Circulation Test

Through a CDI facility, 2500L of ultrapure water having an electrical conductivity of 5 μS/cm or less was produced, and boron was mixed to prepare boric acid water having a concentration of about 26 mg/L, and used in the test. The prepared boric acid water was treated with boron by continuously operating two 1m^3/hr SD-ELIX equipment for about 300 minutes. The effluent water of CDI became the influent water, and the effluent water of SD-ELIX_1 became the influent water of SD-ELIX_2. The effluent water of SD-ELIX_1 and 2, and the electrolyte water of SD-ELIX_1 and 2 were collected as CDI effluent water tank for circulation test.

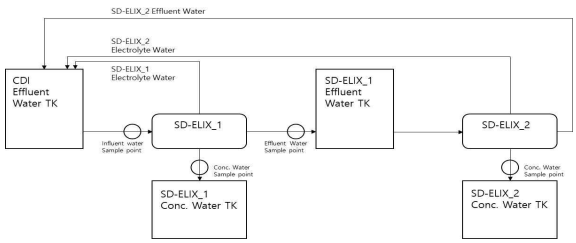

Figure 2. Serial Module (2500L) Recycle Test Mimetic diagram

The test was carried out for a total of 300 minutes, and since the influent water of SD-ELIX_2 equipment uses the effluent water of SD-ELIX_1 equipment, the

SD-ELIX_1 equipment was operated from about 10 minutes later. Sample collection was performed by collecting SD-ELIX_1 influent water, SD-ELIX_1 effluent water, SD-ELIX_1 concentrated water, and SD-ELIX_2 concentrated water at 5, 10, 30, 60, 120, 180, 240, and 300 minutes in the same way as the 1000L recycle test. In the case of concentrated water, SD-ELIX_1 and 2 were collected and stored in a separate tank.

3. Results

3.1 Single Module (1000L) Circulation Test

Table 1. Single Module (1000L) *Circulation* Test Data

	Influent		Effluent		Concentrate	
Time	Conc	EC	Conc	EC	Conc	EC
min	ppm	μS/cm	ppm	μS/cm	ppm	μS/cm
0	55.10	4.785				
5	47.29	2.658	8.68	0.805	113.66	40.92
10	44.07	2.411	17.42	1.260	148.07	54.21
30	36.63	1.756	21.66	1.804	240.55	141.4
60	27.80	1.309	13.95	1.063	199.63	113.3
120	7.61	1.048	7.50	0.771	102.15	38.97
180	8.07	0.995	5.31	0.918	52.19	14.96
240	5.65	0.596	4.45	0.552	25.59	5.60
300	4.40	0.604	4.04	0.755	15.88	3.35

As a result of the circulation test for 300 minutes, the concentration of the influent water was 4.40 mg/L from the initial 55.10 mg/L. In the case of effluent water, the boron concentration increases until 30 minutes after the start of the test and then decreases. After that, it was diluted by the generated water cycle, and the concentration of both influent water and the concentrated water tended to decrease.

3.2 Serial Module (2500L) Circulation Test

Table 2. Serial Module (2500L) *Circulation* Test data

SD-ELIX_1						
	Influent		Effluent		Concentrate	
Time	Conc	EC	Conc	EC	Conc	EC
min	ppm	μS/cm	ppm	μS/cm	ppm	μS/cm
0	26.26	9.109				
5	26.14	8.730	2.83	0.508	89.32	48.57
10	26.25	8.884	4.19	0.609	111.79	60.94
30	23.60	7.985	6.95	0.638	158.82	82.94
60	17.46	6.121	4.72	0.496	137.81	66.89
120	10.71	3.999	3.6	0.679	86.92	31.93
180	6.43	2.248	2.66	0.623	57.41	18.2
240	3.74	1.574	2.52	14.9	36.2	13.11
SD-ELIX_2						
	Influent		Effluent		Concentrate	
Time	Conc	EC	Conc	EC	Conc	EC
min	ppm	μS/cm	ppm	μS/cm	ppm	μS/cm
10	4.129	0.609	N.A	0.666	3.71	47.53
30	6.95	0.638	N.A	0.371	6.14	24.08
60	4.72	0.496	N.A	0.361	9.47	24.2
120	3.64	0.679	N.A	0.404	13.18	27.77
180	2.66	0.623	N.A	0.374	10.81	18.42
240	2.52	14.9	N.A	0.215	8.23	13.5
300	2.23	0.59	N.A	0.261	7.07	11.38

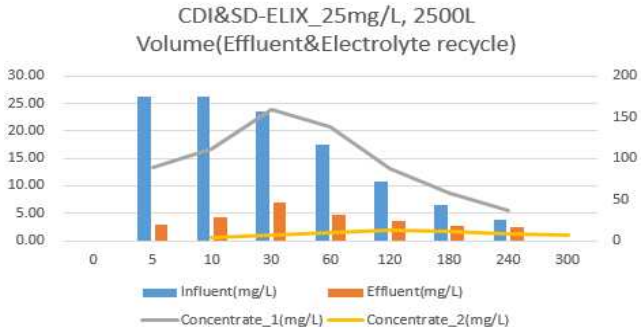

Figure 3. Graph of Boron concentration of Influent, Effluent, Concentration_1 and 2 water

As a result of the series recycle test for 300 minutes, the concentration of the influent water was 2.23 mg/L at the initial 26.26 mg/L after 240 minutes.

The boron concentration of the initial influent water of SD-ELIX_2 was 4.129 mg/L, and the boron concentration of the effluent water was not detected. The concentration of concentrated water also showed a low boron concentration of up to 13.18 mg/L due to the low concentration of the initial influent water. It was confirmed through experiments that processing efficiency can be increased through a series recycle test.

4. Conclusions

In this study, CDI equipment and SD-ELIX equipment were used to lower the boron concentration of the boron containing exhaust water discharged from the nuclear power plant. In the single module (1000L) recycle test, the influent water decreased from the initial concentration of 55mg/L to 4.40mg/L during 300 minutes. In the serial module (2500L) recycle test, the concentration of boron was close to 0.23 mg/L and the effluent water was close to 0 mg/L during 240 minutes. In the future, we will conduct experiments that can increase the processing capacity through parallel recycle test.

Acknowledgements

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20191510301070).

REFERENCES

[1] Tagliabue, M., Reverberi, A. P., & Bagatin, R. Boron removal from water: needs, challenges and perspectives. *Journal of Cleaner Production*, *77*, 56-64, 2014.