Development of Small Modular Boron-containing Liquid Radwaste Treatment System

So Jung Shim, Dae Seong Choi, Ji Sup Yoon, Chang Heon Lee, Young-Ku Choi*
NDRI(Nuclear Decommissioning Research Institute), A-614, 17, Techno 4-ro, Yuseong-gu, Daejeon(34013)
**Corresponding author: choiyk.09@ndri.co.kr*

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1. Introduction

In the case of light-water reactors, boric acid is added to the primary coolant to control the nuclear fission reaction rate of the reactor. In particular, during the planned preventive maintenance period, since high-concentration boric acid water is discharged due to equipment drainage, etc., it shows a relatively higher value than the boron concentration of the discharged water during normal operation. Therefore, in this study, the small modular liquid radwaste treatment system including a boron removal module was developed, and the removal performance of boron, Co, and Cs using the system was verified.

Fig. 1. Small modular liquid radwaste treatment system

2. Methods and Results

2.1 Small module boron-containing radioactive waste liquid treatment system

The small modular boron-containing radioactive waste treatment system developed in this study consists of three modules responsible for physical particle removal, boron removal, and radionuclide removal, and can be applied in series, parallel, and independently linked to the LRS system of a nuclear power plant. Figure 2 below shows the touchscreen section of the system.

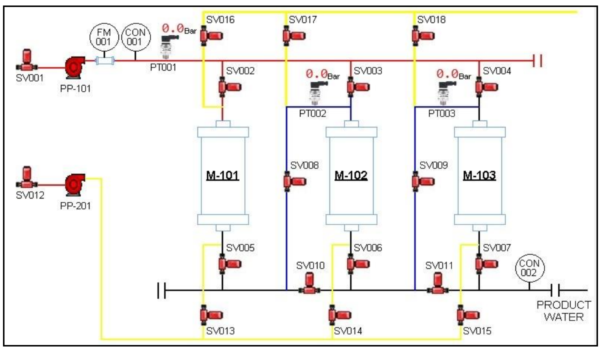

Fig. 2. Touchscreen section of the system

Module 1(M1) is composed of a metal sintered filter module, module 2(M2) is composed of an anion exchange module, and module 3(M3) is composed of a cation exchange module. Table 1 shows the touch screen operation method for evaluating the independent performance of each module, and Table 2 shows the touch screen operation method for evaluating the performance during the linkage operation of the metal sintered filter and each ion exchange module.

Table 1. Independent operation method for each module

Module	Touchscreen Operation
M-1	SV001-PP101-SV002-SV005-SV010-SV011-P/W
M-2	SV001-PP101-SV003-SV006-SV011-P/W
M-3	SV001-PP101-SV004-SV007-P/W

Table 2. Module linked operation method

Module	Touchscreen Operation
M 1-2	SV001-PP101-SV002-SV005-SV008-SV006-SV011-P/W
M 1-3	SV001-PP101-SV002-SV005-SV016-SV009-SV007-P/W
M 2-3	SV001-PP101-SV003-SV006-SV009-SV007-P/W
M1-2-3	SV001-PP101-SV002-SV005-SV008-SV006-SV009-SV007-P/W

2.2 Manufacturing of simulated waste solution

Boric acid(H_3BO_3, 99.5%) of Samchun Chemical Co., Ltd., cobalt nitrate($Co(NO_3)_2 \cdot 6H_2O$) of JUNSEI, cesium chloride(CsCl) of Daejung Chemicals & Metals Co., Ltd. was used as reagents for the production of simulated waste solution. The concentration of boron was set to 200 ppm, which is the average boron concentration during the Overhaul period. In addition, since the concentration of Co and Cs in the actual NPP effluent is very low, it was arbitrarily set to 50 ppm.

Table 3. Simulated waste solution production concentration

	Reagent	Purity (%)	Mass Ratio	Conc. (ppm)	Input amount (g/L)
B	H_3BO_3	99.5	0.17	200	1.151
Co	$Co(NO_3)_2 \cdot 6H_2O$	98	0.20	50	0.252
Cs	CsCl	99	0.78	50	0.064

2.3 Calculation of reactive resin volume

Amberlite® IRN-78 was used as anion exchange resin for boron removal, and Amberlite® IRN-77 was used as cation exchange resin for Co and Cs removal. The amount of resin required was calculated using their total exchange capacity and density. Table 4 below shows the amount of resin required to adsorb 1 L of simulated waste solution.

Table 4. Amount of ion exchange resin required per liter of simulated waste solution

	200 ppm Boron solution	50 ppm Co solution	50 ppm Cs solution
Anion exchange resin	10.4 g/L	-	-
Cation exchange resin	-	1 g/L	1 g/L

2.4 Evaluation of the removal efficiency of the system

In order to verify the removal rate of the system, the removal rate was measured when modules 1-2, 2-3, and 1-2-3 were operated in conjunction, and is shown in Table 5 and Figures 3 to 5.

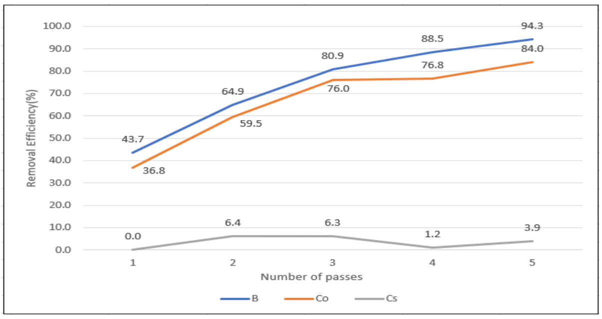

Fig. 3. Removal efficiency when module 1-2 is passed

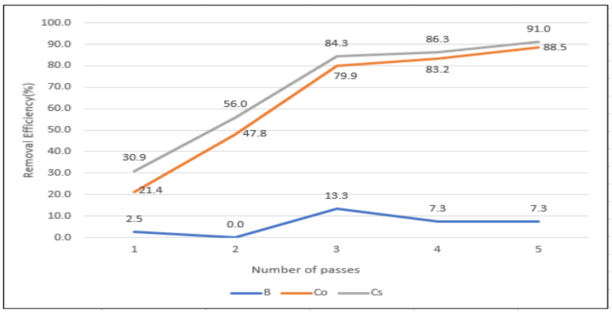

Fig. 4. Removal efficiency when module 1-3 is passed

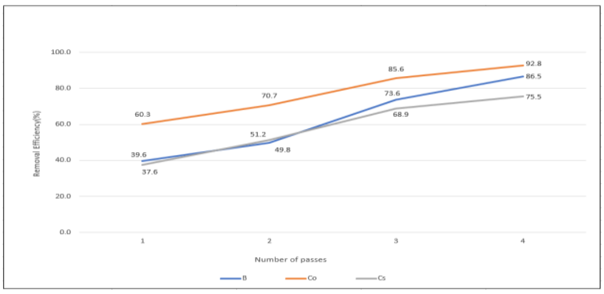

Fig. 5. Removal efficiency when module 1-2-3 is passed

Table 5. Result of the system verification test

Module Type		M 1-2	M 1-3	M 1-2-3
Concentration of Co (ppm)	Before Treatment	65.84	65.84	65.84
	After Treatment	5.81	3.78	0.06
	Removal Efficiency	91.2	94.3	99.9
Concentration of Cs (ppm)	Before Treatment	57.4	57.4	57.4
	After Treatment	0.0001	22.2	0.0001
	Removal Efficiency	99.9	61.3	99.9
Concentration of B (ppm)	Before Treatment	225.7	225.7	225.7
	After Treatment	3.07	215.56	6.02
	Removal Efficiency	98.6	4.5	97.3

3. Conclusions

In this study, a compact modular liquid waste system was developed based on experiments to remove boron, Co, Cs from a simulated waste solution containing boron. This system can be applied in conjunction with an LRS in emergency situations or used independently during overhaul period of NPPs.

Since the metal sintering filter in module 1 of this system can be used semi-permanently through the backwash line, it has the effect of reducing secondary waste. In addition, the performance of both ion exchange modules of modules 2 and 3 shows a removal efficiency of 95% or more. If this system is used in connection with the existing LRS during the overhaul period when the boron concentration rises rapidly, it is expected to contribute greatly to reducing waste and securing economic feasibility.

4. Acknowledgements

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