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Development of a boron separation/enrichment process using electro-chemical technology and coagulation process to treat the concentrated boron

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1. Introduction

Large amounts of boric acid are being used in PWRs to control reactor power. Due to the dilution operation, liquid waste containing boron is continuously generated during the operation period.

Regarding the recovery and removal of boron in the waste, in nuclear power plants built in the 1970s and 1980s, a boron evaporator in a boron recovery system and a waste evaporator in a liquid waste treatment system were installed. But recently constructed nuclear power plants are applying RO and ion exchange resin instead of evaporators in LRS and this RO and ion exchange resin cannot remove the boron in waste water because the boron in wastewater exists as a form of boric acid at normal condition of NPP. In order to remove boron from waste water, it is essential to ionize it by adding an alkaline chemical such as NaOH. However, it is impossible to add an alkaline chemical to the waste water in the monitor tank, which is the final discharge facility of the LRS in a nuclear power plant, to remove boron because another waste liquid treatment facility is required.

As mentioned above, it is difficult to remove boron with RO and ion exchange resins, and since the global trend is increasingly restricting the boron concentration in wastewater, a new technology that can remove boron in wastewater is required.

This study was conducted to develop a technology using electrochemical technology capable of separating and concentrating boron in waste water without adding additional alkaline chemicals.

2. Methods and Results

2.1 Concept of Boron Removal System

The characteristics of the final discharge water of the monitor tank in the nuclear power plants are shown in table 1. The boron concentration is up to 50 ppm, but can increase to 500 ppm in special case. The pH is 6~7, and the conductivity is 10 to 50 ㎛/㎝.

Table I: Characteristics of Wastewater in Monitor Tank

Category	Unit	Value	Note
pH	-	6~7	
Boron	ppm	5~50	Max. 500
Conductivity	㎛/㎝	10~50	

The boron removal technology of this study is largely divided into three technologies (Fig. 1). The first is a process to remove particulate impurities by pretreating the waste liquid flowing from the monitor tank with MF or UF, and the second process is to remove ionic impurities first using CDI (Capacitive Deionization) and then selectively separate boron by applying electrochemical technology (ELIX, Electrochemical Ion-exchange). The third is a process in which concentrated boron is precipitated using a coagulant, then the supernatant is discharged and the precipitate is dehydrated with a screw decanter.

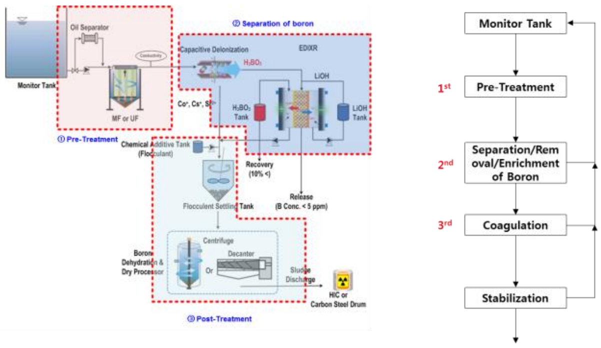

Fig. 1. Flow diagram of boron removal system

2.2 Design and Experiment of Boron Removal using ELIX

Fig. 2 shows a conceptual diagram and flow-sheet of the technology for removing boron from the waste liquid in the monitor tank using ELIX, an electrochemical technology.

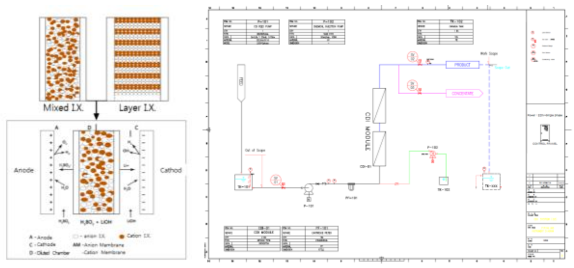

Fig. 2. Schematic diagram of boron removal systems using electrochemical separation technology

The conceptional drawing of separation/enrichment of boron using ELIX is shown in Fig 3 and Fig 4 shows the ELIX device manufactured for the boron removal experiment in this study. Using ELIX, boric acid in wastewater can be ionized and separated/concentrated without raising the pH using chemicals such as NaOH.

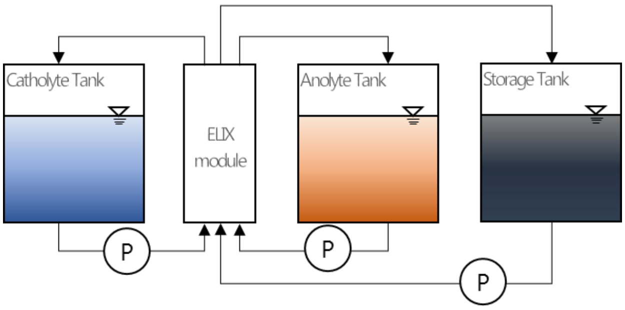

Fig. 3. Conceptional drawing of boron removal system using ELIX.

Fig. 4. ELIX System manufactured in this study.

Fig. 5 shows the experimental results of boron removal using ELIX. Starting at the initial 2,000 ppm, boron was found to have decreased to about 400 ppm, with more than 80% removed after seven hours. Finally, when 14 hours were reached, more than 99% of boron were removed.

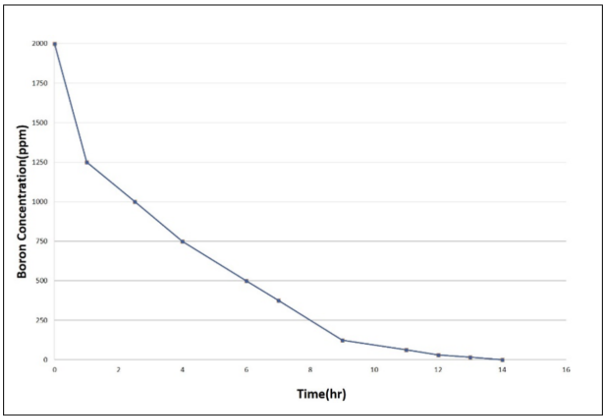

Fig. 5. Result of boron removal efficiency using ELIX

2.3 Coagulation Experiment of concentrated boron

The boron separated and concentrated by ELIX was subjected to a coagulation/precipitation process using a boron selective coagulant, and the precipitate was dehydrated using a specially designed screw decanter.

Table Ⅱ: Condition of boron coagulation

pH	Boron Conc.	Chloride Conc.	Coagulant injection	Time
7.3	620 ppm	10,000 ppm	4.5 w/w %	30 min

The experiment for coagulation was conducted as following process.

1) Add the coagulant to the reactor and stir for 30 minutes in reactor.
2) After 20 minutes of sedimentation, separate the supernatant.
3) After sedimentation, the supernatant is discharged.
4) The sediment is dehydrated using a decanter for solidification.
5) This sludge is solidified to send disposal site. after drying.

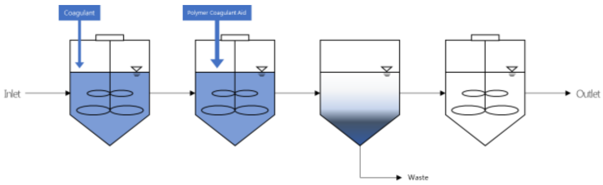

Fig. 6. Coagulation process for concentrated boron.

3. Conclusions

From the result of conducting a basic experiment with the concentration/separation process of boron, it was confirmed that high concentration of boron was concentrate in this process. In the future, it will be determined the optimum concentration and coagulation condition in the process of ELIX operation.

In addition, it is determined that system optimization is necessary by confirming the coagulant selection and coagulation efficiency in the coagulation experiment of boron.

ACKNOWLEDGMENTS

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REFERENCES

[1] Ministry of Environment, Rules on Drinking Water Quality Standards, Inspection, etc, 2018.