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Evaluation of boron separation and concentration characteristics of electrochemical modules for selective removal of boron from nuclear power plants.

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1. Introduction

Due to insufficient site area, domestic nuclear power plants can affect the environment if multiple devices are operated on one site and even a trace amount of pollutants that may affect the environment after power generation are simultaneously discharged. Therefore, not only radioactive substances but also ionic substances such as boron should be discharged as minimally as possible.

In the case of nuclear power plants that use evaporators in LRS, boron emissions were relatively small, but in new nuclear power plants such as OPR1000 and APR1400, there is no suitable facility to remove boron because they consist of RO and ion exchange resin without evaporator. The World Health Organization (WHO) has set a limit of 2.4 mg/L of boron in drinking water, and the average boron concentration in seawater is known to be 4.6 ppm.

There are various commercial separation techniques such as evaporation, reverse osmosis (RO), and ion exchange in relation to boron removal. However, the evaporation method consumes high energy for the crystallization of boric acid, the ion exchange technology generates a large amount of waste resin, and the reverse osmosis method has a disadvantage in that the removal efficiency of boric acid at neutral pH is limited. Therefore, there is a need for an approach to boron treatment that is more efficient, generates less waste, and reduces costs.

Electrochemical water treatment technology is a technology widely applied in the ultrapure water production process and can be applied to selective removal of boron. For example, the EDI applied as the last process of the ultrapure water manufacturing process contains two electrodes, that is, a permeable anion exchange membrane and a cation exchange membrane through which ions can selectively penetrate between the cathode and the anode. Also, the diluted compartment is filled with an ion exchange resin that improves the transport of ions under the driving force of the potential, reduces the electrical resistance of the stack, and prevents concentration polarization effects.

The potential applied based on the constant voltage induces ion migration to the surface of the membrane through the ion exchange resin bed. During EDI operation, water electrolysis produces hydrogen and hydroxide ions that regenerate the resin without using chemicals.

Boron removal is known to vary mainly depending on pH, temperature, pressure, salinity of inflow water, and other parameters, and in this study, the boron removal efficiency according to various conditions was evaluated after modifying the existing electrochemical module into a SD-ELIX(specially designed electro-chemical ion-exchange).

2. Methods and Results

2.1 SD-ELIX System

The SD-ELIX system was used in continuous driving mode as an SD-ELIX stack, power supply, and other components such as tanks, pumps, switches, and flowmeters. There are three flows of water, each cation and anion passing through the cation exchange membrane and the anion exchange membrane is stored as a concentrated water storage tank by mixing the effluent of the two dilution sections are stored as treated water storage tanks.

An adjustable power supply was applied to apply a constant potential to the SD-ELIX system, and all experiments were conducted in a constant voltage (48V) mode. Samples were taken in the inlet tank, the treatment tank, and the concentrated water tank every 0, 5, 10, 30, 60, 90, 120, 180, and 240 min, respectively, for each time period. The contaminated water was diluted with RO treated water to prepare a boric acid solution of 50 to 250 mg/L and driven. The treated water was returned to the raw water tank to reduce the boron concentration in the raw water as much as possible. The boron concentration of the sample was analyzed using a potentiometer, and the pH and electrical conductivity were measured using an Orion multi-water quality meter.

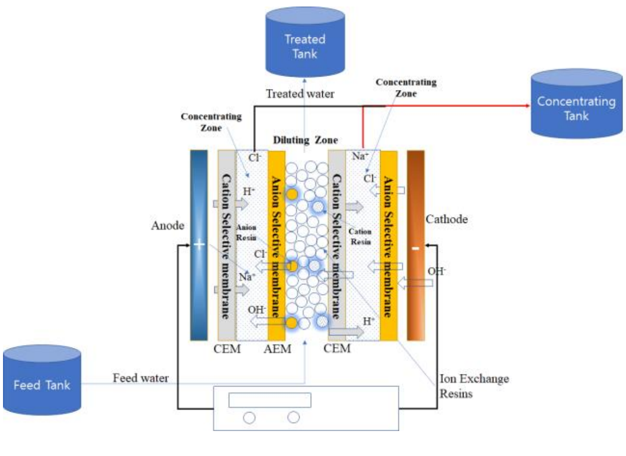

Fig 1. Electrochemical boron removal system.

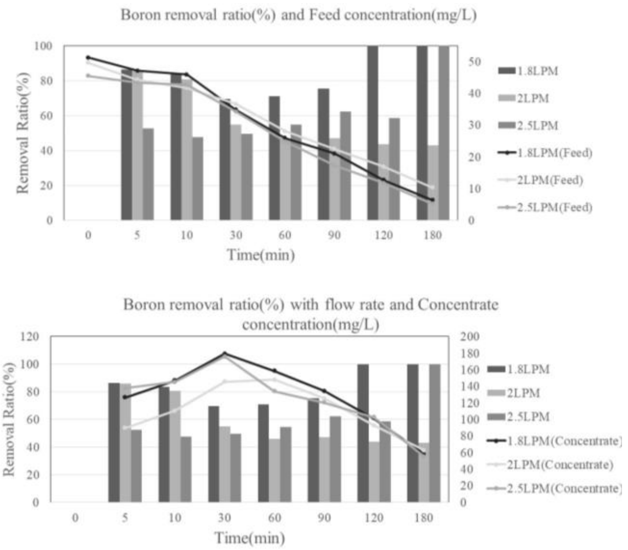

Fig 2. Boron removal ratio with variables.

The boron concentration of the initial inflow water tended to decrease over time. The water quality of concentrated water also reached its peak until the initial 30 minutes, but tended to decrease in line with the decrease in the inflow water concentration.

The boron removal rate was in the range of 70 to 99% with respect to the initial boron concentration of 25 to 250 mg/L, and the treatment efficiency tended to decrease as the boron concentration of the inflow water increased. The boron removal rate tended to decrease as the flow rate increased, and the flow rate showed the highest boron removal rate at 1.8 LPM. As the flow rate decreases, it is expected that the residence time in the system increases, the ionization of boric acid increases, and the number of borate ions exchanged with the resin increases. On the other hand, performance degradation due to the use of electrochemical modules is also observed, and it seems that the timing of regeneration through chemical cleaning should be considered.

In the future, it is necessary to shorten processing time by considering the optimal flow rate conditions and conductivity conditions and converting electrochemical modules into series or parallel. On the other hand, when the water quality of the inflow water is lowered to less than 5 ppm, the amount of concentrated water also increases, so research to minimize concentrated water is needed.

3. Conclusions

The performance was evaluated by scaling up the existing laboratory-scale boron selective removal system. It was confirmed that the boron treatment efficiency tends to vary according to the conditions of the electrical conductivity, boron concentration, and inflow flow rate of the water by the pretreatment, and at the same time, the performance of the electrochemical module is degraded. In addition, it is necessary to reduce the amount of boron wastewater through research to reduce the volume of boron-containing concentrated water through SD-ELIX treatment after lowering the conductivity of boron-containing concentrated water over time.

Acknowledgements

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