Boron Removal from Aqueous Solution by Ion-Exchange Resin: Column Sorption-Elution Studies*

T. E. Bektaş, N. Öztıirk
Osmangazi University, Faculty of Engineering and Architecture, Dept. of Chemical Eng., 26480, Eskişehir

ABSTRACT: A column sorption-elution study was carried out by using a strong base anion exchange resin (Dowex 2x8) for the removal of boron from aqueous solution. The breakthrough curve was obtained as a function of feed flow rate and capacity value of resin was calculated. The boron on the resin was quantitatively eluted with 0.5M HCl solution at different flow rates. Recycle use of resin was studied by the use three sorption-elution-washing-regeneration-washing cycles. Total capacity values remained almost the same after three sorption-elution-regeneration cycles.

1. INTRODUCTION

Boron is widely distributed in the environment, occurring naturally or from anthropogenic contamination, mainly under the form of boric acid or borate salts. Boron is found in the earth's crust at an average concentration of about 10 mg/L. The most important commercial borate products and minerals are borax pentahydrate, borax, sodyum perborate, bone acid, colemanite and ulexite.

Turkey possesses over 60 percent of the world's boron reserves. The production of boron compounds has increased m recent years, due to increasing demands for these compounds m nuclear technology and production of insulation and textile grade fiber, borosilicate glass, heat-resistant materials, catalysts, enamels, glazes and agricultural products (Simonnot et. al., 2000; Okay et.al, 1985; Şener and Özkara, 1988; Şahın, 2002; Badruk et. al., 1999).

Boron is essential element for the cultivation of fruits and vegetables. However, if it is present İn amounts larger than required, it becomes toxic (Nadav, 1999).

Some surface waters contain boron as boric acid. For instance, boron more than 10 mg/L frequently occurs in hot spring waters In addition, industrial wastewaters also contain boron at unacceptable concentrations (Jyo et al., 2001).

There are several phsicochemica! treatment processes typically used to remove boron from water and wastewater. These are adsorption with inorganic adsorbents, ion exchange, solvent extraction, membran processes and ultrafiltration (Badruk et. al., 1999; Recepoğlu and Beker, 199J).

Among these methods, the ion exchange process is most extensively used. Ion exchangers are solid and suitably insolubilized high molecular weight polyelectrolytes which can exchange their mobile ions for ions of equal charge from the surrounding *médium. The* resulting ion exchange is reversible and stoichiometric with the displacement of one ionic species by another on the exchanger The column process is the most common and efficient ion exchange methods (Helfferich, 1962)

This study was financially supported as a Project (200315038) by Research Fund of Osmangazi University

The present study describes the column performances of Dowex 2x8 anion exchange resin for boron removal from the aqueous solutions.

2. EXPERIMENTAL WORK

2.1 Materials

The Dowex 2x8 was a strong basic anionic exchange resin. It was supplied from Supeico. The particle size of Dowex 2x8 is between 100 and 200 mesh and moisture content of resin is 37%. The functional group in resin is benzyl-dimethylethanolamine. Before the ion exchange resin was used in the experiments, it was pretreated. It was first washed several times using distilled water. Then the resin was immersed in 2N NaOH solution for 48 h and finally washed again distilled water.

The aqueous solution for the experiments was prepared by dissolving an appropriate amount of boric acid (Merc product) in the distilled water to 600 mg B/L.

2.2. Column Sorption-Elution of Boron

The column experiments were performed in a glass column (0.7 cm in diameter and 15 cm length). Glass wool was placed in the bottom of the column and then packed with a 3 mL wet-settled volume of resin. The flow rate of aqueous solution entering the ion exchange column was controlled by a peristaltic pump (ATTO SJ 1211 Model) at 13 and 15 bed volumes per hour. The 1.5 mL of effluent was collected using a fraction collector (Spectra/chrom CF-1) and analysed by the spectrophotometer (HACH DR-2000) using Carmine Method. The column elution experiments were performed at 13 and 15 BV/h flow rate using 0.5 M HCl solution. The absence of boron in the effluent indicated the completion of elution. The recycle tests were conducted using the Dowex 2x8 (3 mL) and by passing the column 600 mg B/L H^BOı solution at 15 BV/h. After the elution step performed with 0.5M HCl solution at 15 BV/h and the washing step with distilled water, the resin was regenerated using 2N NaOH and finally washed with distilled water. Another loading cyle was then carried out.

3. RESULTS AND DISCUSSION

Fig. 1. shows the breakthrough curves of boron obtained at 13 BV/h. Breakthrough curves in this diagram generally permit a good description of the processes m ion exchange columns since a breakthrough capacity characteristic for a column under given conditions can be assigned to these curves. Boron concentration in the effluent was very low up to 23 bed volumes. Then the concentration of boron increased gradually. The resin was exhausted at about 30 BV. The breakthrough and total capacity values of the resin are given in Table 1. The elution profile is given Fig. 2. Elution is the process opposite of the sorption and sorbed substance is obtained. Boron loaded on the resin was quantitatively eluted with 0.5M HCl. The boron concentration in the eluate reached 9312 mg/L. This value is 15.6 times higher than that of the boron concentration in the feed solution.

Table 1. Column performances of Dowex 2x8

Breakthrough capacity (mgB/mLresin)	13.94
Total capacity (mg B/mL resin)	15
Elution (%)	97

Fig. 3. shows the results of the column experiments with various flow rates. The experiments were conducted by passing H3BO3 solution (600 mg B/L) through the column at 13 and 15 BV/h. If the flow rate is higher, the H3BO1 solution does not have enough time to react with the ion échange resin, which consequently results in shorter BV. The loaded resin was quantitatively eluted with 0.5 M HCl at 13 and 15 BV/h. The resulting elution profile is shown in Fig 4.

In order to demonstrate the reusability of the Dowex 2x8 resin, the sorption-elution-washing-regeneration-washing cycle was repeated three times. Recycle use of Dowex 2x8 was studied at 15BV/h. The resulting breakthrough curves are given in Fig.5. Elution profiles of each cycle are shown in Fig.6. Total capacity values remained almost the same after three sorption-elution-regeneration cyles.

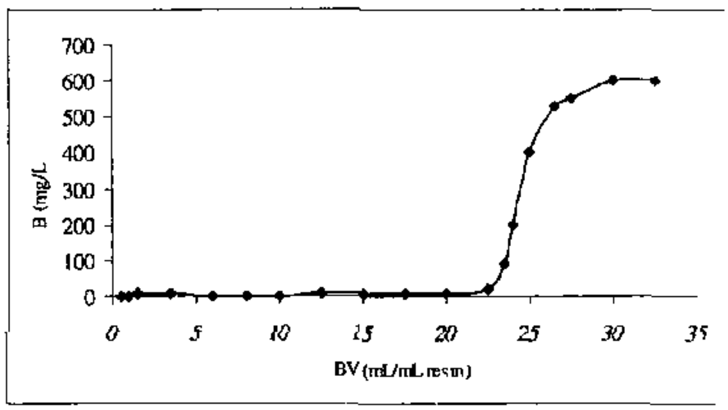

Figure 1 Breakthrough curves of boron obtained at 13 BV/h

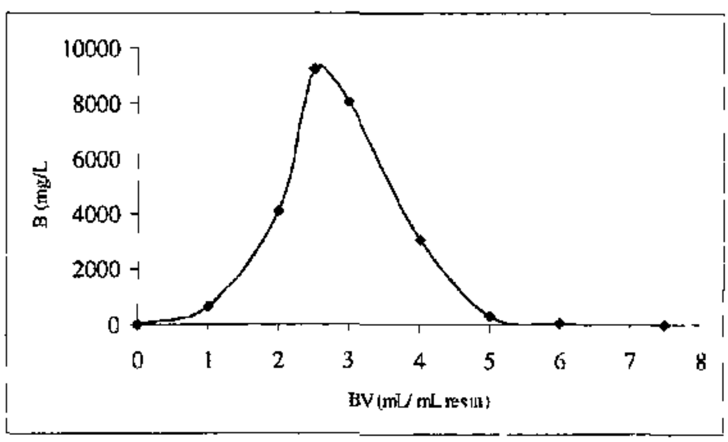

Figure 2 Elution profile of boron

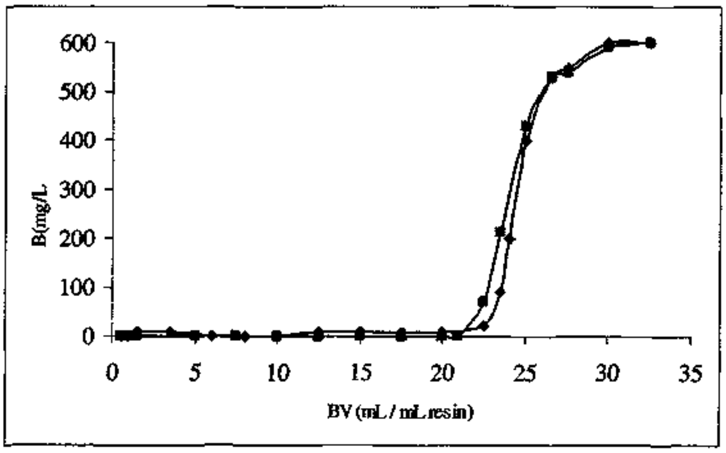

Figure 3. Effect of flow rate on breakthrough capacity of Dowex 2x8 (• 13BV/h, • 15 BV/h)

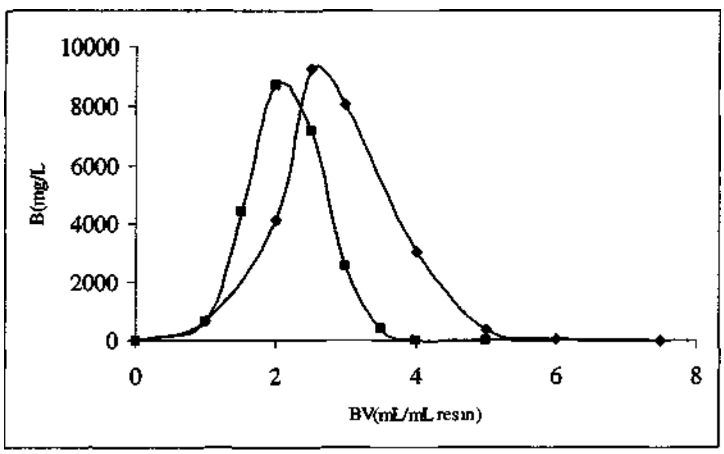

Figure 4. Elution profiles of boron at different flow rate (• 13 BV/h, • 15BV/h)

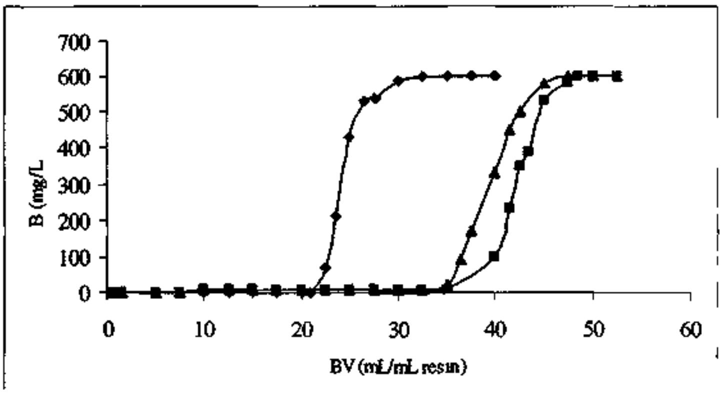

Figure 5 Recycle use of Dowex 2x8 for boron removal (•!, *mC,* A III cycles)

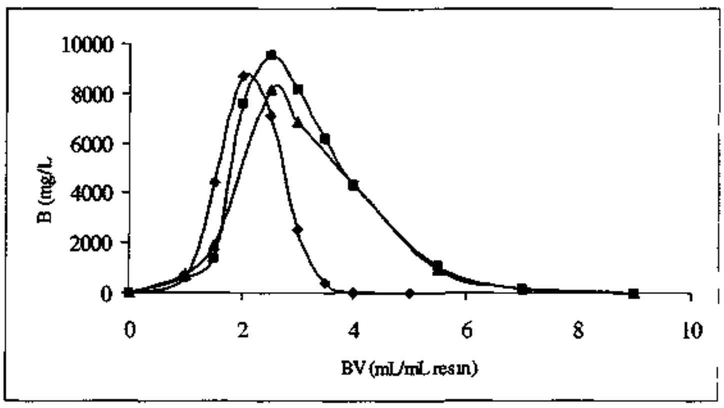

Figure 6 Elution profiles of boron(**♦I, ■II, ▲III cycles)**

4.CONCLUSIONS

For the column ion exchange experiments, Dowex 2x8 anionic ion exchange resin was used. The sorption capacities and elution efficiency calculated by graphical integration of the area above the breakthrough curves are about 15 mg B/mL resin and 97 %, respectively. The boron concentration in of the eluate reached 9362 mg/L. This value is 15.6 times higher than that of initial boron concentration (600 mgB/L) in H1BO3 solution. Columnar sorption of boron from H3BO3 solution was studied at 13 and 15 BV/h flow rates. The breakthrough point shifted to right more with a decrease is flow rate. The capacity increases with the first cycle. After the 2^{nd} and 3^{rd} cyle the capacity did not noticeably change. The results showed that Dowex 2x8 could be repeatedly used in boron sorption studies with slight losses in its initial sorption capacity.

REFERENCES

Badrak, M. 1998. *Removal of Boron from Geothermal Brines of Kızıldere by Means of Co-Precipitation and Ion-Exchange Methods,* The Degree of Doctor Thesis, Dokuz Eylül University.

Badruk, M., Kabay, N., Demircioğlu, M., Mordoğan, H., Ipekoğlu, U. 1999. *Removal of Boron from Wastewater of Geothermal Power Plant by Selective Ion-Exchange Resins. I. Batch Sorption-Elution Studies,* Separation Science and Technology, No. 34(13), 2553-2569

Helfferich, F., 1962. *Ion Exchange,* McGraw-Hill Book Company, Inc. New York.624p.

Jyo, A., Aoki, S., Uchimura, M., Yamabe, K., Sugo, T. 2001. *Behavior of Chelating Fibers Having Polyol Groups in Column Mode Adsorption of Boric Acid,* Analytical Sciences, No. 17,1211-1214

Nadav, N. 1999. *Boron Removal from Seawater Reverse Osmosis Permeate Utilizing Selective Ion Exchange Resin,* Desalination, No. 124, 131-135

Okay, O., Güçlü, H., Soner, E., Balkaş, T. 1985. *Boron pollution in The Simav River, Turkey and various Methods of Boron Removal,* Water Res., No.7, Vol. 19,857-862

Recepoglu, O., Beker, Ü. 1991. *A Preliminary Study on Boron Removal from Kmldere/Turkey Geothermal Waste Water,* Geothermics, No. 1/2, Vol. 20, 83-89

Simonnot, M., Castel, C, Nicolai, M., Rosin, C, Sardin, M., Jauffret, H. 2000. *Boron Removal from Drinking Water With A Boron Selective Resin: Is The Treatment Really Selective?,* No.1, Vol.34, 109-116

Şahin, S. 2002. *A Mathematical Relationship for The Explanation of Ion Exchange for Boron Adsorption,* Desalination, No. 143, 35-43

Şener, S., Özkara, M. 1998. *The Boron Pollution of Simav Creek Waters and Its Effects on The Soils and Agricultural Crops of Balıkesir Region,* Plants and Pollutants in Developed and Devolopmg Cauntries. Edited by M.Ahmet Öztürk.