Boron removal from produce water through adsorption

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Abstract. Boron (B) is essential for the development and functioning of organisms, involving their growth, health, and development of plants, animals, and humans. Nevertheless, the increasing use of boron in various applications has led to environmental problems and health issues. Several separation technologies have been employed to remove boron, and adsorption is one such technology that utilizes adsorbents to address solutions containing extremely low levels of boron. This finding investigates the residual boron from a synthesized solution through adsorption, using CRB05 as the adsorbent. The impact of adsorbent dosage, contact time, boron concentration, and pH on residual boron was examined. The findings indicate that the pH plays a substantial role in the residual boron efficiency from all adsorbents. The highest residual of boron was achieved at pH 4.5, adsorbent dosage 1125 mg/L, time 255 minutes, and concentration 1150 mg/L with 98% removal. Adsorption of boron using CRB05 proved to be an effective method for recovering boron from the synthesis solution. The findings of this study enhance our comprehension of the adsorption behavior of CRB05 and provide insights into the optimal operating conditions for efficient boron removal.

1 Introduction

In current history, there has been a greater focus on source pollutants discovered in water that are poorly eliminated through traditional techniques used in water treatment. Boron is one of these contaminants. Even though boron is a required source of nutrients for humans and certain plants, the distinction between inadequate and excessive amounts is minimal [1-3]. B has been found in nature as a material with other elements. Nevertheless, boron has yet to be discovered. When boron is present in water at concentrations below 0.3 mg/L, it has
beneficial effects on human consumption and irrigation. However, elevated levels of boron can be detrimental to the health of humans, plants, and animals [4, 5]. Based on the existing drinking water quality guidelines established by the World Health Organization (WHO), the suggested level of boron in drinking water is set at 2.4 milligrams per liter (mg/L) [6, 7]. Since the impact of B on human health is not fully investigated, many current recommendations are still provisional and subject to further research into boron toxicity in humans.

The most effective method for removing boron from water seems to be the utilization of B-selective ion exchange resins, which utilize microporous polystyrene matrices containing active N-methyl-d-glucamine groups [8, 9]. Because this group contains two vicinal hydroxyls, (H₃BO₃) and (B(OH)₄ can make a steady complicated with the adsorbent. Moreover, diffusion-reaction in resin particles significantly impacts ion exchange kinetics [10]. This reaction could be reduced by using an adsorbent with a bigger total surface area [4, 6]. The greater the overall surface area of the adsorbent, the faster the ion exchange procedure [11].

As of now, chelating resins have proven to be the most capable and targeted adsorbent for recovery B from synthesis solution with low B concentrations. Chelating resins have a microporous polystyrene sequence connected to functional hydroxyl groups, which are frequently in the cis position of vis-diol resins [12].

In this study, CRB05 commercial adsorbents were used to evaluate the effects of the adsorbent on boron elimination from aqueous solution at various values of solution pH, the concentration of boric acid, and adsorbent dosage. A special focus was placed on the effectiveness of pH in the elimination of Boron.

2 Materials and method

In this study, commercial adsorbents such as CRB05 from Mitsubishi Chemical were used. Another reagent was purchased from Segam Malaysia. The B synthesis solution (30%) was created using a high-quality H₃BO₃ reagent. Before commencing the adsorption experiments, precise solutions were meticulously prepared by mixing H₃BO₃ with distilled water [6].

The batch adsorption experiments involved adding different adsorbents and initial boron concentrations to volumetric flasks with a 500 mg/L capacity. This was achieved by using a 30% stock solution. The adsorbent dosage and concentration were adjusted across a range of 300 mg/L to 2000 mg/L. The pH of the boron solutions was adjusted by diluted HCl and NaOH to study the influence of pH. The flasks were then placed on an orbital shaker and agitated at 140 rpm for different durations. After the designated duration had passed, a filter membrane was employed to separate the adsorbent from the liquid. The remaining concentration of boron was assessed using a Spectrophotometer, employing the carmine method [4, 13].

3 Result

3.1 Impact of the Adsorption Dosage and pH on B Recovery

The adsorption dosage refers to the quantity of adsorbent introduced into the solution. Increasing the adsorption dosage generally leads to higher boron recovery due to the increased availability of adsorption sites. However, there is usually an optimal dosage beyond which further increases may not significantly enhance boron recovery. The pH factor has significant importance in boron recovery through adsorption. The pH affects the charge of both the boron ions and the adsorbent surface [14].
Boron separation was observed to rise with an increment of adsorbent dosage. The increased overall surface area and the greater number of binding sites on the surface of the resin contribute to the higher boron absorption with the adsorbent dosage [15]. It should be noted that boron removal was highly effective when the resin particles and feed solution were in contact for 255 minutes at a resin dosage of 1125 mg/L and pH 2. Similarly, at a resin dosage of 2000 mg/L and pH 4.5, significant sorption of boron occurred after 480 minutes. It had been discovered that at constant adsorbent dosage, B separation reduced with increment concentration of boron (Figure. 1) because of the faster saturation of the resin's absorption rate.

Numerous species of soluble boron exist in aqueous media, based on different variables such as adsorbent dosage, and in particular, pH, that have a significant impact on boron speciation and, consequently, its adsorption/removal [3, 16].

![Fig. 1. Effect of time, adsorbents dosage, and pH on Boron Recovery.](https://doi.org/10.1051/bioconf /20237302002)

### 3.2 Impact of the Concentration and pH on B Recovery

In experiments conducted at a consistent temperature of 25 °C, the impact of pH on the effectiveness of boron recovery was assessed. Various boron concentrations and dosages were employed for the evaluation [4]. As depicted in Figure 2, the highest sorption occurred at pH 4.5, resulting in a remarkable recovery efficiency of 98%. Conversely, the lowest efficiency for boron removal was observed at pH 7. The impact of pH on the uptake of boron can be explained by considering the dissociation of $\text{B(OH)}_3$ in water and the formation of a bidentate complex between the borate ion and the adsorbents present in the resin.

The impact of the initial boron concentration on the adsorption capacity of CRB05 is illustrated in Figure 2. As the initial boron concentration increases, the equilibrium adsorption of boron also increases. This trend continues until it exhausts a point where it stabilizes at a
constant time. The optimum observed adsorption recovery for CRB05 were 24, 18, and 15 mg/L, respectively, for various boron concentrations and durations [4, 6, 17]. The concentration and pH of the water significantly impact the efficiency of boron recovery. Higher initial concentrations of boron can enhance removal capacity up to a saturation point, beyond which further increases in concentration yield minimal gains. The water's pH affects the boron's speciation and the interaction with the adsorbent, with an optimal pH range typically yielding the highest removal efficiency [18].

Fig. 2. Effect of time, concentration, and pH on Boron Recovery.

4 Conclusion

The adsorbent CRB05 demonstrated promising potential for the recovery of boron from produced water. The experimental results illustrated that CRB05 exhibited a high adsorption capacity for boron ions, leading to significant boron removal from the solution. The adsorption dosage was found to be a critical parameter affecting boron recovery. Increasing the dosage of CRB05 resulted in higher boron removal efficiency up to a certain optimum dosage. Beyond this point, further increases in adsorbent dosage did not significantly enhance boron removal, indicating the saturation of available adsorption sites. Maximum boron elimination was obtained at a pH 4.5 value with a dosage of 1125 mg/L and a contact time of 255 minutes.
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References


