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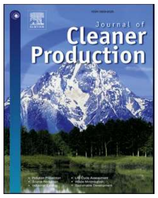

Boric acid recovery from wastewater by chromatographic separation and mathematical modeling

Zehra Kole [a], Zehra Betul Ocal [a,b], Philip Isaac Omwene [c], Gulfem Soydemir [a], Bulent Keskinler [a], Ahmet Karagunduz [a,*]

[a] *Department of Environmental Engineering Gebze Technical University, 41400 Kocaeli, Turkey*
[b] *Department of Environmental Engineering, Faculty of Engineering, Sinop University, 57000, Sinop, Turkey*
[c] *Faculty of Agriculture and Environmental Sciences, Muni University P.O. Box 725 Arua, Uganda*

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ABSTRACT

The new approaches in industrial wastewater management underscores the importance of reclaiming valuable materials. Within the boron industry, the generation of substantial wastewater containing preliminary boron species is a significant concern. This study focuses on recovering boric acid from boron production wastewater, addressing the challenge of separating impurities like sulfate, calcium, and magnesium. The methodology adopts chromatographic separation using a cation exchange resin in two forms: (1) Finex CS10GC cation exchanger in Na^+ form and (2) Finex CS10GC cation exchanger in Ca^{2+}/Mg^{2+} form. Notably, the Finex CS10GC ion exchanger in Na^+ form achieves a separation efficiency of 95.5 % at a flow rate of 5 mL/min with a 0.20 bed volume (BV) loading. In contrast, the Ca^{2+}/Mg^{2+} loaded resin achieves a separation efficiency of 23.3 % at the same flow rate. As the boron loading rate decreases to 10 %, the separation efficiency increases to 42.6 %. The flow rate also plays a crucial role, as an increase corresponds to a decrease in separation efficiency. Notably, the Finex CS10GC ion exchanger in Na^+ form consistently exhibits superior separation efficiency and band resolution. A mathematical model is introduced to simulate the effective separation of boric acid from other impurities. The quality of the recovered boric acid conforms to the standard grade (Merck KGaA), exhibiting a purity level within the range of 99.5–100 %, suggesting substantial economic value. The proposed recovery process contributes significantly to environmental preservation by mitigating waste discharge, exemplifying a noteworthy commitment to resource conservation.

1. Introduction

Boron (B) is a valuable mineral widely distributed in soil, rocks, surface waters, and underground reservoirs. Globally, there are over 200 boron minerals, each containing varying proportions of magnesium, sodium, or calcium. Among the most notable boron minerals are colemanite, borax, ulexite, and kernite (Mermer and Şengül, 2020). As boron mining and processing activities expand, substantial amounts of boron-containing wastes are generated leading to environmental pollution concerns through waste discharge (Bolan et al., 2023). Additionally, boron finds its way into the environment through irrigation, fertilizer application, and wastewater release. Wastewater from boric acid plants is predominantly composed of liquid residues from crystallization and washing processes. Typically, boric acid production wastewater contains approximately 3000–6000 mg/L of boron (or 18,000–36,000 mg/L as H_3BO_3), along with various ions, including calcium, magnesium, and elevated sulfate concentration (Öcal et al., 2024). Furthermore, active boron input pathways such as geothermal waters (volcanic springs) and the weathering of boron-containing minerals significantly contribute to boron pollution in rivers and streams (Omwene et al., 2018).

The treatment of boron-containing water and wastewater has been extensively explored in the literature, with the ion exchange process utilizing chelating resins standing out as one of the most effective methods for boron removal from water (Kabay et al., 2004). However, its application is restricted in wastewater treatment due to elevated boron concentrations. Although membrane processes exhibit effectiveness at higher pH levels (Koseoglu et al., 2008), their utility is hindered by scaling when there are elevated concentrations of calcium and sulfate.

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[*] Corresponding author. Department of Environmental Engineering, Gebze Technical University, 41400, Gebze-Kocaeli, Turkey.
E-mail address: akaragunduz@gtu.edu.tr (A. Karagunduz).

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