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Comparative study on the treatment of simulated brominated butyl rubber wastewater by using bipolar membrane electrodialysis (BMED) and conventional electrodialysis (ED)

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ABSTRACT

A large amount of wastewater containing sodium bromide (NaBr) is generated during the production of brominated butyl rubber. In our previous job, bipolar membrane electrodialysis (BMED) was used to regenerate hydrobromic acid (HBr) and sodium hydroxide (NaOH) from a simulated NaBr wastewater. To give a comparison with previously presented research paper, a desalinization of sodium bromide by using ED was also performed. The effects of operation parameters, such as current density, sodium bromide concentration, and initial acid and base concentrations in the concentrate, on desalinization were analyzed. In comparison, BMED has higher desalinization ratio and current efficiency, and much lower voltage drop and energy consumption. The process cost is estimated to be 0.82 $/kg NaBr for BMED and 1.01 $/kg NaBr for ED. Notably, BMED can also regenerate NaOH and HBr. Therefore, BMED will be more economically attractive and environmental benignity due to the regeneration of useful resource and prevention of secondary pollution.

1. Introduction

The brominated butyl rubber with excellent performance has won the favor of the tire industry in recent years. The demand for the brominated butyl rubber is increasing with the development of domestic tire industry. Much wastewaters containing sodium bromide with the concentration about 16,000 mg/L are usually produced in the preparation of brominated butyl rubber. Such huge amounts and high concentration of sodium bromide wastewater should to be treated before discarding, or it will not only cause serious environmental pollution [1], but also impair people's health and may even cause death.

Because of the BMED process advancements, economical competence, and environmental benignity, it has been used in several fields, such as the chemical industry [2–5], biotechnology [6–9], food processing [10,11], and environmental protection [12–15]. So in the previous paper [16], this wastewater was treated by using BMED. The results showed BMED was adequate to salt convention due to its effective functional integration of the water splitting in bipolar membranes [17,18] and the salt dissociation in conventional electrodialysis (ED). Actually, ED can also be applied to treat the brominated butyl rubber wastewater [19].

Accordingly, in this paper, in an attempt to find a more suitable treatment approach, experiments were performed on the desalination of sodium bromide by using ED. Subsequently, a comparative study between BMED and ED was conducted. The influences of operation parameters, such as salt concentration, initial base and acid concentration as well as the current density on the performance of process and the process economics were also investigated. The comparison will also lead to a better understanding of these two processes and lay a foundation for treating the industrial waste solution discharged in the process of preparation of brominated butyl rubber.

2. Experimental

2.1. Materials

Membranes used in the experiments were Neosepta AMX (anion exchange membrane, Tokuyama Co., Japan), Neosepta CMX (cation exchange membrane, Tokuyama Co., Japan) and Neosepta BP-1 (bipolar membrane, Tokuyama Co., Japan). Their properties were listed in Table 1. All chemicals were of analytical grade and used as received. Distilled water was used throughout.

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Table 1
Properties of the membranes applied to the BMED and ED stacks.

Membrane type	Thickness (μm)	Ion-exchange capacity (IEC) (meq g^{-1})	Area resistance (Ω cm^2)	Voltage drop (V)	Efficiency (%)
Neosepta BP-1	200–350	–	–	1.2–2.2	>98
Neosepta AMX	120–180	1.4–1.7	2.0–3.5		
Neosepta CMX	220–260	1.5–1.8	2.0–3.5	–	–

* The data are collected from the product brochure provided by the company.

2.2. Apparatus

Schematic diagrams of the experimental setup for the configuration of the ED and BMED are illustrated in Fig. 1. Specifically, the stacks are comprised of (1) a cathode and an anode, which are made of titanium coated with ruthenium; (2) an anion-exchange membrane, a cation-exchange membrane and bipolar membrane. The stacks of ED and BMED were shown in Fig. 1a and b, respectively. The effective area of each membrane was 7.07 cm^2. These membranes were arranged between anode and cathode. The stacks had five compartments. Chambers were separated by Plexiglas spacers (thickness = 1 cm) which were used to ensure the sealing of the stack. Two electrodes were connected with a direct current power supply (WYL1703, Hangzhou Siling

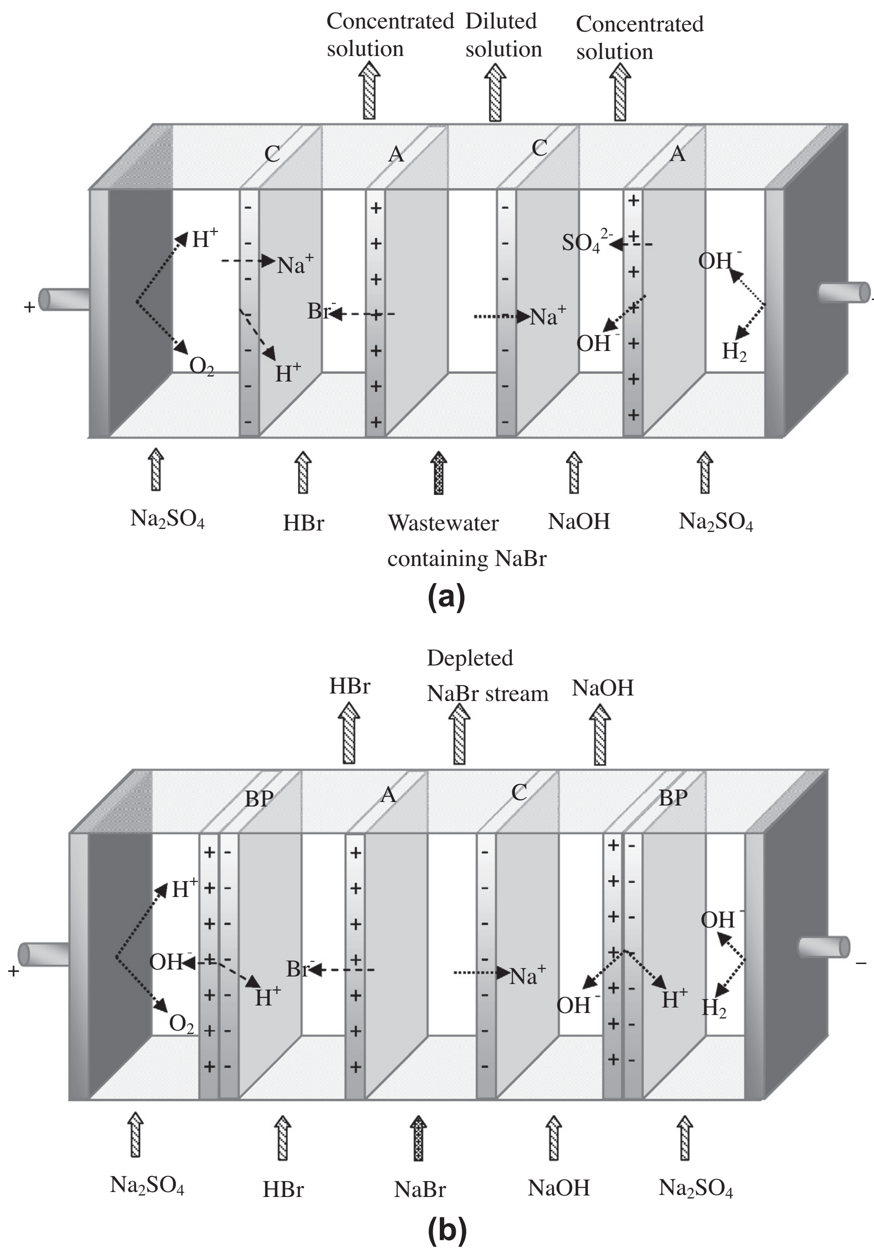

Fig. 1. Schematic of BMED and ED system operating principle (BP, bipolar membrane; C, cation exchange membrane; A, anion exchange membrane; (a) conventional electrodialysis; (b) bipolar membrane electrodialysis.).