A Comparative Study of ED and BPED Technologies for Ammonia Recovery from Wastewater

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Abstract

Ammonia is a common pollutant in wastewater, and its removal is essential to prevent environmental issues such as odors and eutrophication, which can harm aquatic ecosystems and human health. While traditional treatment methods are energy-intensive and costly, ammonia has garnered attention as a carbon-free hydrogen source in the context of the global shift toward carbon neutrality. Wastewater, particularly supernatant from anaerobic digesters and leachate from sludge dewatering, often contains high ammonia concentrations, offering a potential feedstock for hydrogen production. This study compares electrodialysis (ED) and bipolar membrane electrodialysis (BPED) systems for ammonia recovery, aiming to obtain a sustainable hydrogen source from environmental public infrastructures. Energy consumption, current efficiency, pH changes, and ammonia recovery rates were thoroughly evaluated for both processes. Results show that BPED leads to higher pH and ammonium hydroxide accumulation, making it suitable for processes like membrane distillation. However, BPED exhibited higher energy consumption and lower current efficiency compared to ED. The findings suggest that both systems have distinct advantages and can contribute to ammonia recovery in wastewater treatment, supporting the development of sustainable ammonia recovery strategies for hydrogen production.

Keywords: Ammonia, Wastewater, Net–Zero, ED, BPED

1. Introduction

Ammonia is a representative pollutant in wastewater and its removal at treatment facilities is essential to prevent odor problems and eutrophication in surface water [1]. While ammonia can be eliminated with physicochemical and biological treatment processes, these methods require a significant amount of energy and high cost for operating [2]. With the global shift toward carbon neutrality (Net-Zero), ammonia is gaining significant attention as a new carbon-free source for hydrogen production because there is no carbon in its form [3]. Importantly, ammonia is commonly found in high concentrations, exceeding 3,000 mg/L, in the supernatant of anaerobic digesters or leachate from sludge dewatering processes. This presents a valuable opportunity to recover ammonia at wastewater treatment plants as a potential feedstock for hydrogen production [4]. Even though various technologies are available for ammonia recovery, electrodialysis (ED) has gained attention as a popular process [5].

Electrodialysis (ED) uses cation exchange membranes (CEM) and anion exchange membranes (AEM) to selectively separate and concentrate ionic substances in solutions [6]. On the other hand, bipolar membrane electrodialysis (BPED) utilizes bipolar membranes to decompose water into hydrogen ions and hydroxide ions when a specific voltage is applied generating both acidic and basic solutions simultaneously from salt solutions without the need for additional chemicals [7].

In this study, we conducted comparative experiments using ED and BPED systems to recover ammonia from wastewater, aiming to obtain a viable hydrogen source in environmental public infrastructures. We thoroughly analyzed and evaluated energy consumption, current efficiency, pH changes, and ammonia recovery rates for each process. Advantages and disadvantages of both processes were critically assessed to support the development of a sustainable ammonia recovery strategy for use in public environmental infrastructure.

2. Result

Fig. 1 shows the change in pH perduring the operation of ED and BPED systems. In the BPED system, due to water dissociation, the concentration of OH^- increased.

Fig. 2 shows the energy consumption (kWh/kg NH_4^+-N) and the current efficiency (%). Compared to the ED, BPED showed higher resistance, resulting in larger energy consumption and lower current efficiency.

In summary, compared to ED, the BPED system resulted in higher pH due to ammonium hydroxide accumulation, which can be effectively utilized in processes like membrane distillation for ammonia recovery.

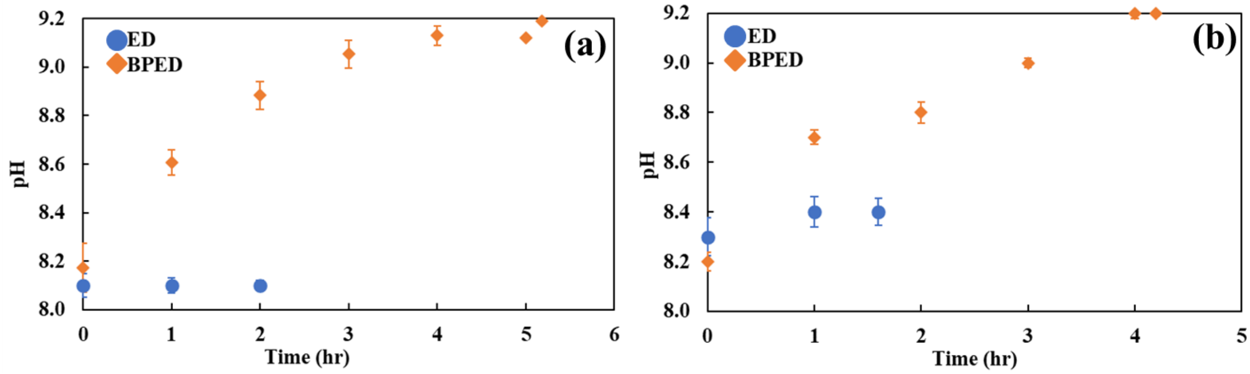

Figure 1. pH & Operating time with ED & BPED of (a) RW.F and (b) RW.S.F

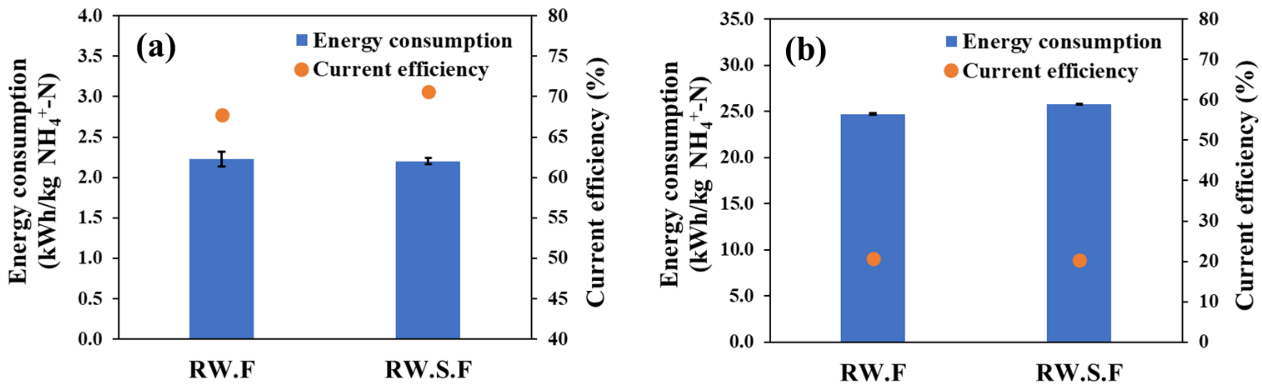

Figure 2. Energy consumption & current efficiency with RW. F & RW.S. F of (a) ED and (b) BPED

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