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Concentration of nitrogen as new energy source from wastewater by electrodeionization

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Abstract

With the popularity of ammonia fuel cell, nitrogen-containing compounds are becoming an alternative energy sources. However, most of those nitrogen compounds, especially ammonia, are dispersed in domestic wastewater and their treatment is often energy consumption. Therefore, the nitrogen retrieval from wastewater is becoming urgently needed of development. Adopting a new five-compartment electrodeionization technology, this paper demonstrates the possibility to concentrate ammonia nitrogen in synthetic wastewater. The result indicates that the optimum current is 0.18 A in artificial domestic sewage with low concentration ammonium ions among 15 mg/L. The nitrogen concentration can be enriched for about 12 times in single stage. The removal rate of nitrogen can reach over 90% with energy consumption of 19.104 g/kW·h. It explores a feasibility of recovering the ammonia nitrogen in wastewater.

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Keywords: electrodeionization; wastewater; urea; ammonium ions; energy; concentration

1. Introduction

Energy shortage is one of the biggest environmental challenges today. It is the most important task for all mankind to change the energy structure and search for new energy sources. As we all know, the energy density of urea is higher compared with compressed or liquid hydrogen which makes it a potential energy[1,2]. In 2009, S. W.Tao's research group had already proposed the direct urine fuel cell which can generate electricity from urea

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directly. Since the emergence of ammonia fuel cell, nitrogen as a kind of new energy has been noticed. However, the source of nitrogen is a tricky issue. Unfortunately, most of nitrogen compounds, especially ammonia, are dispersed in domestic sewage as a waste. About 77% of the energy consumption of sewage treatment is in the activated sludge process of nitrification which consumes energy as high as 45 WJ to remove nitrogen per kilogram[3,4]. Why not will people have retrieved those compounds as useful chemicals? If it would be recovered from wastewater, the nitrogen energy sources can be gained instead of its disposal as a waste.

We are herein concerning about their retrieval methodological development. However, the exiting technologies of nitrogen recovery mainly depend on chemical and biochemical methods, such as struvite recovery process[5], which often exist different defects like the application of the precipitation agent or coagulant aids bringing high cost and secondary pollution and are hard to recover ammonia nitrogen from low-concentration nitrogenous wastewater.

The "electro-dynamic inspissation (EDI)" technology applied in this experiment is a combining process based on the technology of ion exchange and electrodialysis[6,7]. It is not only used to "de-ionize" water to purify it but also is a novel desalination technology for gathering or recovering ions under electro-forces. It overcomes the concentration polarization and chemical regeneration existed in original single process and can treat low concentration solution efficiently. In our previous work, we employed this technology to recover some metal ions as well as carbon dioxide instead of discarding them[8,9]. In this study, a new electrochemical deionization apparatus of five compartments was designed to achieve the continuous regeneration of resin on line without addition of chemicals aiming at recycling the resources of nitrogen. The object of this study was to demonstrate the utilization of the apparatus to recover nitrogen from wastewater, to examine its recovery performance and to evaluate its power consumption.

2. Method

2.1. Materials

Synthetic domestic sewage: its formula is shown in Table 1[10].

Table 1 Formula of synthetic domestic sewage water

Formula	glucose	NH_4Cl	NaCl	$MgSO_4$	$CaCl_2$	$NaHCO_3$	NaOH	K_2HPO_4	trace elements
Quality(g/mL)	0.2	0.11	0.1	0.003	0.004	0.02	0.1	0.028	0.4

Constant volume to 1000mL

Ion exchange resin: the anion exchange resin is D201 macroporous-type strong base and the cation exchange resin is D001 macroporous-type strong acid, which all produced by Hangzhou glory resin Co., ltd.

Ion exchange membrane: anion membrane and cation membrane, produced by Shandong Tianwei membrane technology Ltd.

Equipment: Vertical pressure steam sterilizer, produced by Shanghai Boxun Industrial Co., Ltd. medical equipment factory; Magnetic driven circulating pump MP-6R, produced by Shanghai Xishan Industrial Co., Ltd; 2802 UV-VIS spectrophotometer, etc.

2.2. Experimental apparatus

The five-compartment EDI apparatus is shown in Figure 1. Based on the traditional electrodeionization technology, the anion and cation resin are filled into different compartments and separated by corresponding ion exchange membranes. Under the electric field force, the H^+ migrate faster than OH^-, resulting the pH in concentrated chamber maintain acidic so that the divalent ions in solution will not be precipitated[11]. The chambers of anion and cation resin are connected together. The influent goes through the anion resin chamber in which anions migrate to the concentrated chamber, and then passes through the cation resin so the cations can migrate to it as well. Finally, the concentrated ammonia in concentrating chamber and freshwater in diluting chamber are obtained, respectively.