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Desalination of a thermal power plant wastewater by membrane capacitive deionization

Jae-Bong Lee[a]*, Kwang-Kyu Park[a], Hee-Moon Eum[a], Chi-Woo Lee[b]*

[a]*Environment Structure Research Laboratory, Korea Electric Power Research Institute, Deajeon 305-380, South Korea*
Tel. +82 (42) 865-5221; Fax +82 (42) 865-5725; email: leejb@kepri.re.kr
[b]*Department of Advanced Materials Chemistry, Korea University, Jochiwon 339-700, South Korea*
Tel. +82 (41) 860-1333; Fax +82 (41) 862-5182; email: cwlee@korea.ac.kr

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Abstract

A membrane capacitive deionization (MCDI) system, the one that ion-exchange membranes were added onto a capacitive deionization (CDI) system, has been developed to test desalination performance for power plant wastewater. Several experiments were conducted to compare the MCDI with the CDI in desalination capacity and to determine optimal operation conditions using 1,000 ppm NaCl solution. Salt removal rate of the MCDI system was 19% higher than that of the CDI system. The flow rate and the direct current voltage at which the salt removal rate was the highest were 40 ml/min and 1.2 V, respectively. Desalination performance for the power plant wastewater was investigated at the given operation conditions. The maximum salt removal rate and electric energy consumption were about 92% and 1.96 Wh/L, respectively. It was concluded from this study that the MCDI system could successfully be applied for the reuse of power plant wastewater.

Keywords: Capacitive deionization; Desalination

1. Introduction

Water is an essential and fundamental resource in thermal power plants with various purposes: a make-up for boiler feed water, cooling bearings and equipment, and various plant services. Raw water used for these purposes at most power plants in Korea is drawn from a river basin. However, several power plants located in the capital area depend on a public enterprise for the supply of water. Accordingly, water bills for the plants are increasing year after year. So, the plants consider treatment and reuse of wastewater from various processes: water treatment, demineralizer system, etc. Since the treated wastewater contains only inorganic ions, it can be reused as raw water for various purposes after the ions are removed with cost-effective and environmentally friendly deionization technology.

*Corresponding authors.

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In order to remove ions from salty water, some kinds of processes such as ion exchange, reverse osmosis, and electrodialysis are used at present. Recently, capacitive deionization (CDI) using capacitive adsorption has been suggested to lower water treatment cost and prevent environmental pollution without the disadvantages that other processes have [1,2]. CDI is energy-efficient because it is operated at low voltages (0.8–1.4V) without high-pressure pumps, thermal heaters or high direct current voltage. In addition, this process is environmentally friendly because it requires no chemicals. In CDI, fouling associated with reverse osmosis or electrodialysis is also minimized because no sustained concentrates are formed.

CDI is an electrosorption process that removes inorganic ions by charge separation and acts as a "flow through" capacitor [3]. In CDI, an aqueous solution containing dissolved inorganic salts passes between matching pairs of activated carbon cloth electrodes on which electric potential is applied. Inorganic ions are held at the charged electrode surfaces and removed from aqueous solution. When the electrodes are saturated with ions, they can be regenerated by applying the reverse potential to allow the adsorbed ions to be released into the purge stream. This process might be important for future applications for water purification [4]. Although several studies for CDI have been conducted recently, they have been mainly carried out to develop new carbon materials to use as CDI electrodes [5,6].

In this study, in order to reuse a thermal power plant wastewater a membrane capacitive deionization (MCDI) system that shows higher desalination performance compared to CDI was developed and its salt removal rate and electric energy consumption were investigated. In addition, its optimal operation conditions such as the flow rate and the direct current voltage were determined. And the feasibility of applying the MCDI system to the reuse of a power plant wastewater was determined.

2. Experimental

2.1. Electrode material

The activated carbon cloth (ACC) made from phenolic resin (Kuraray Chemical, Japan) was used for MCDI and CDI electrodes. The specific surface area was obtained by the BET method [7]. Table 1 shows the main characteristics of the ACC.

Table 1
Main characteristics of ACC used for the electrode

Commercial name	CH900-10
Thickness, mm	0.6
Specific surface area, m^2/g	1117
Raw material	Phenolic resin

2.2. Ion-exchange membranes

The ion-exchange membranes (Tokuyama, Japan) were used to adsorb the ions selectively on the electrodes. The cation-exchange membrane is selectively permeable to cations and the anion-exchange membrane is selectively permeable to anions. Their low electric resistance affects the consumption of electricity for the MCDI. Their main characteristics are shown in Table 2.

2.3. MCDI and CDI performance

Adsorption capacity of ions on electrodes was measured using bench-scale MCDI or CDI apparatus shown in Fig. 1. Aqueous solution with applied flow rates of 40–100 ml/min was pumped into the stack by a peristaltic pump (PP-600DW, Poong lim Co., Korea) at the bottom and exited at the top. The direct current voltage of 0.8–2.0 V was applied by a rectifier (Agilent E3633A, USA). Conductivity was monitored by a conductivity meter (Swan Unicon 4, Swiss). Ion concentration was determined by ion chromatography (Dionex-DX500) and inductively coupled plasma spectrometry (Shimadzu, ICPS-1000).