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Determination of Energy Consumption in an Electrodialysis Reversal Pilot Plant

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Introduction

Only about 0.01% of earth's water is fresh water in lakes and rivers where humans can easily use it., To meet human needs for fresh water, some of earth's abundant saline water must be desalinated – that is, converted to fresh water through artificial processes. There are multiple desalination technologies, and one of the most common is electrodialysis reversal (EDR). EDR is a membrane-based, electrically driven separation process in which ions, as a result of their attraction to two electrically charged electrodes, migrate through ion-selective semi-permeable membranes. EDR systems consist of multiple cell pairs, and every cell pair includes a cation-exchange membrane, an anion-exchange membrane, and spacers. The multiple cell pairs, in turn, are placed between two electrode compartments. A schematic of an EDR system is shown in Figure 1.

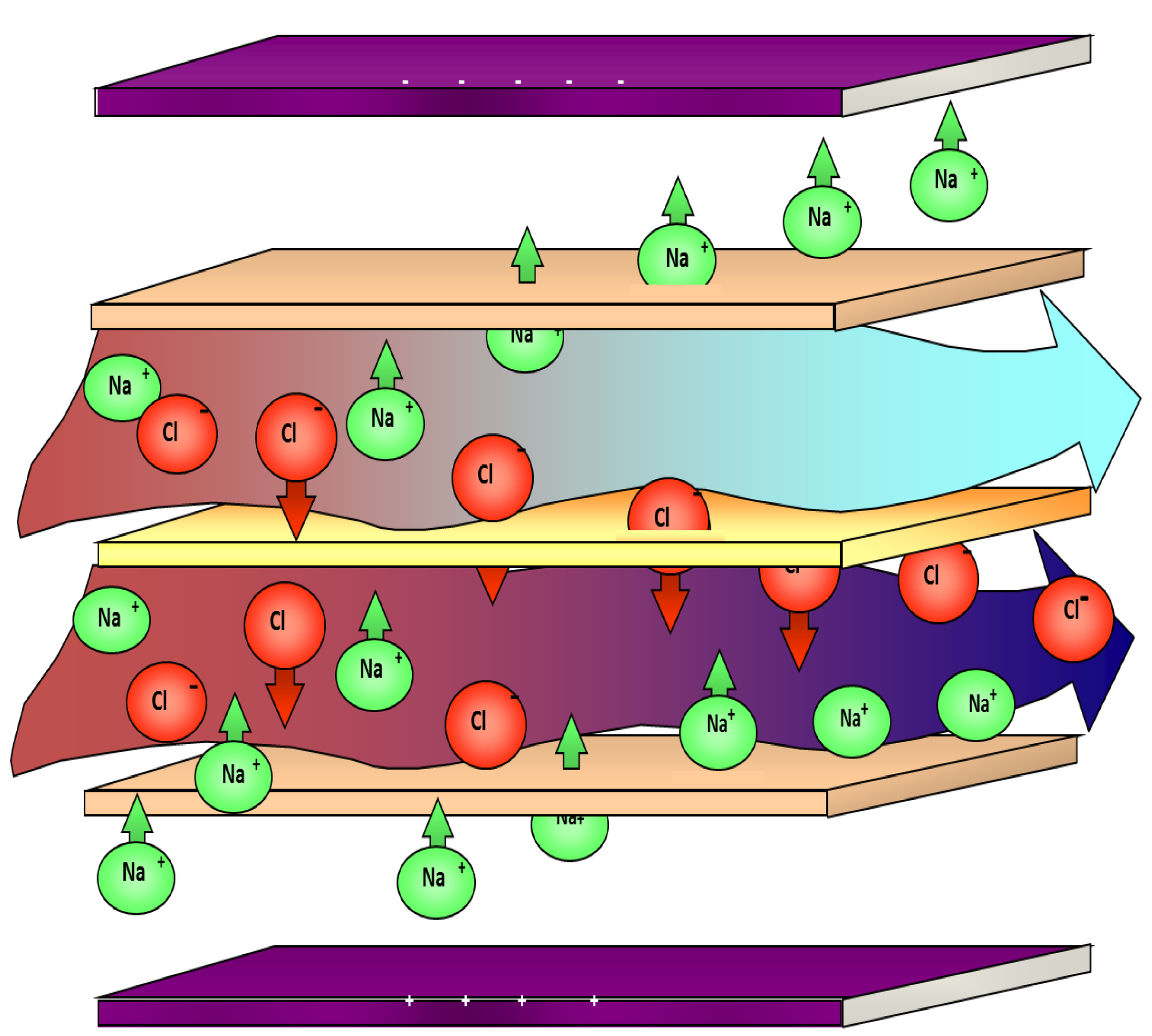

Figure 1. Schematic of an EDR stack.

EDR is widely used to desalinate seawater, and it also shows promise to desalinate brackish water with lower salinities, such as the groundwater in many southwestern states. This technology is already efficient compared to most other desalination approaches, but we can facilitate the deployment of additional EDR systems and alleviate water scarcity by increasing the technology's efficiency still further.

Experimental Approach

For desalination systems such as EDR, efficiency typically is measured in terms of specific energy consumption (SEC), which quantifies how much energy the system uses to produce a given volume of product water. Lower SECs indicate higher efficiency.

It has been established that operating conditions and system design elements affect the efficiency of EDR units, and many of these factors are controllable. Therefore, in this research, we varied operating conditions and electrode designs to find a regression model that predicts the SEC of EDR systems on the basis of applied voltage, feed salinity, feed flowrate, and electrode design. By optimizing the regression model within practical constraints, the efficiency of EDR systems can be maximized.

The experiments were conducted at the Brackish Groundwater National Desalination Research Facility in Alamogordo, NM, on a General Electric Company pilot-scale EDR system with an influent feed capacity of 12 gpm. The pilot-scale system, shown in Figure 3, used 40 cell pairs and commercial-size spacers, membranes (CR67 and AR908), and full-face electrodes.

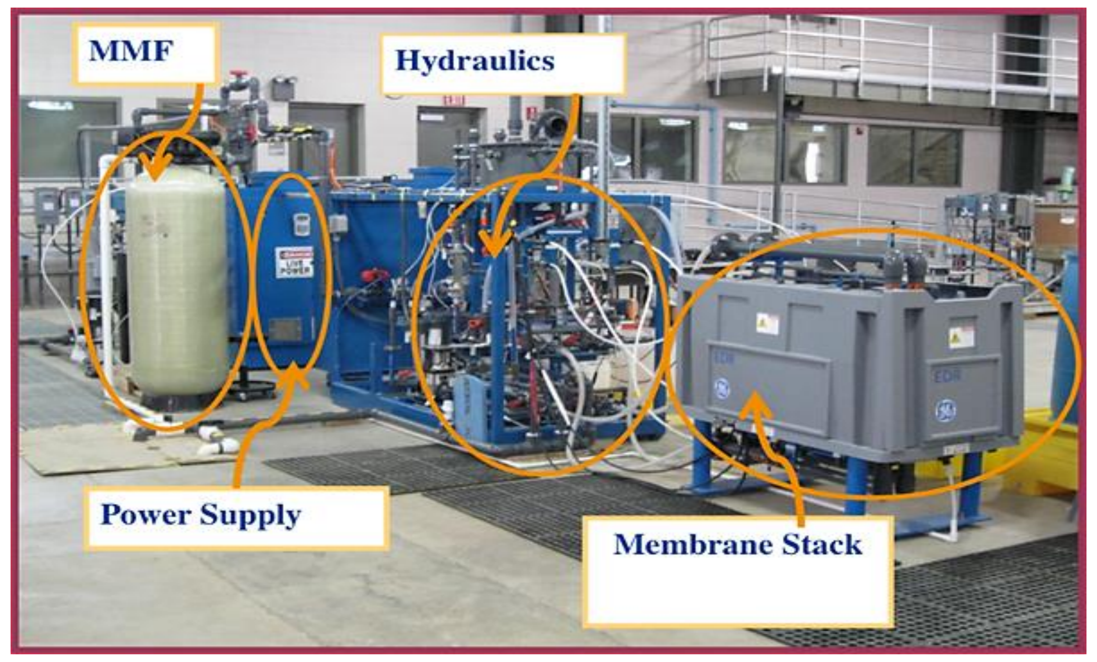

Figure 2. EDR pilot-scale system manufactured by General Electric.

The experiments used a full factorial design with the factors and levels shown in Table 1. For all experiments, the recovery rate was 85%, the temperature was 15-20 ºC, and the reversal period was 15 min. At steady-state operating conditions, the outlet concentration of the dilute stream was measured. Then, the desalting ratio was calculated and the total consumed energy was recorded.

Table 1. Different Controllable Factors and Their Levels

Factors	Levels
Feed Salinity (ppm)	Low: 1700 (well1) Medium: 3700 (mixed) High: 6000 (well2)
Voltage (V)	30 32.5 35 37.5 40
Feed Flowrate (gpm)	Low: 7 Medium: 9 High: 11
Electrode design	Full Recessed Tapered

Primary Results

The overall regression model for the SECs of pilot-scale EDR systems is below.

SEC = 0.0013 + 0.0413/Flow Rate + 6.475E-05 * Voltage^2 * Conductivity/Flow Rate

The model exhibited a very good fit with the experimental data. The effects of individual factors on SEC are shown in Figures 3 through 6.

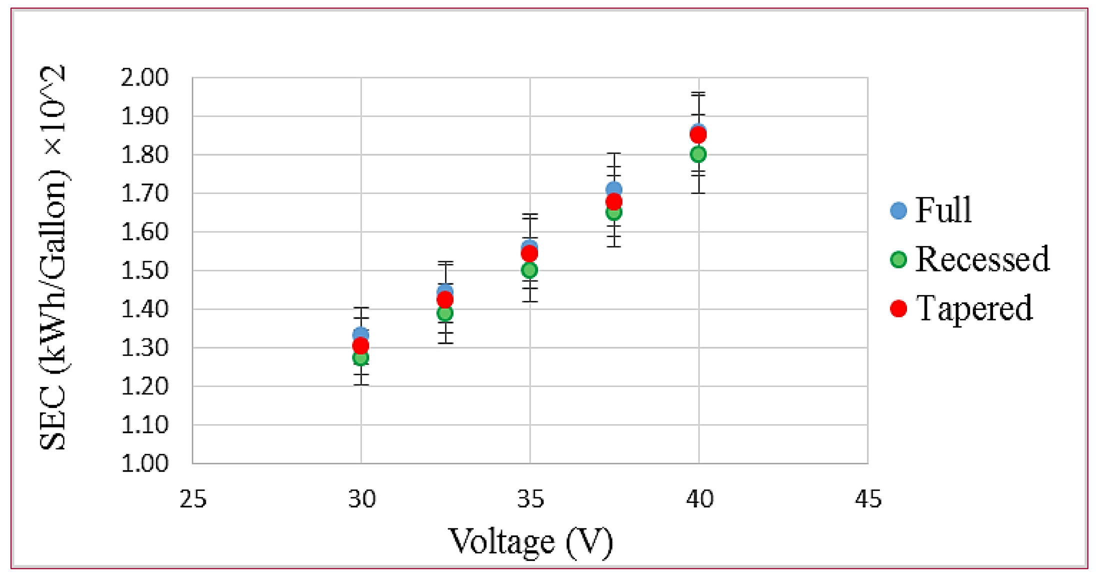

Figure 3. Effect of stack voltage on specific energy consumption

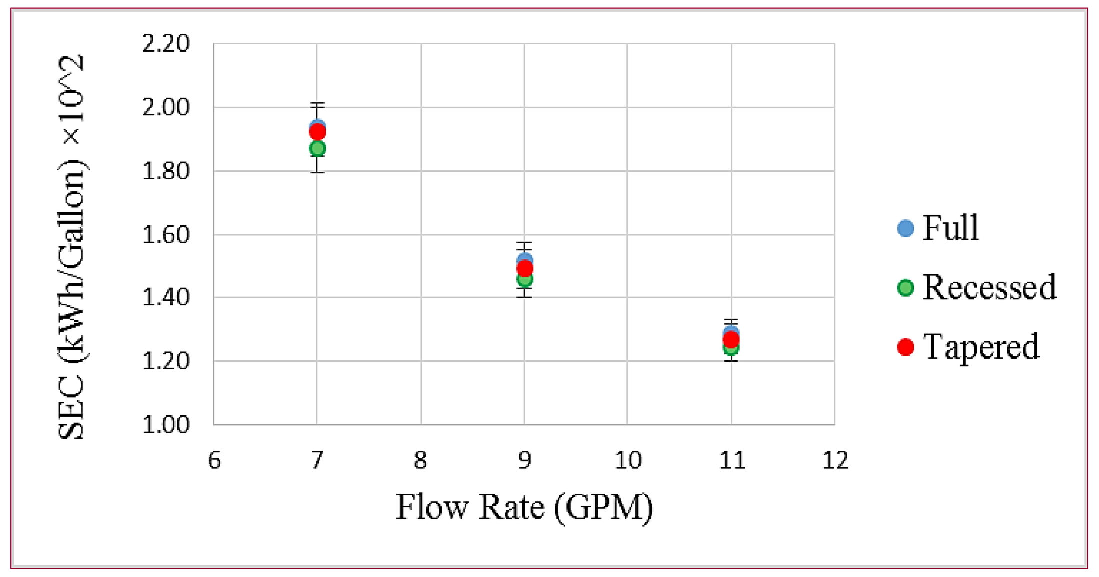

Figure 4. Effect of flow rate on specific energy consumption

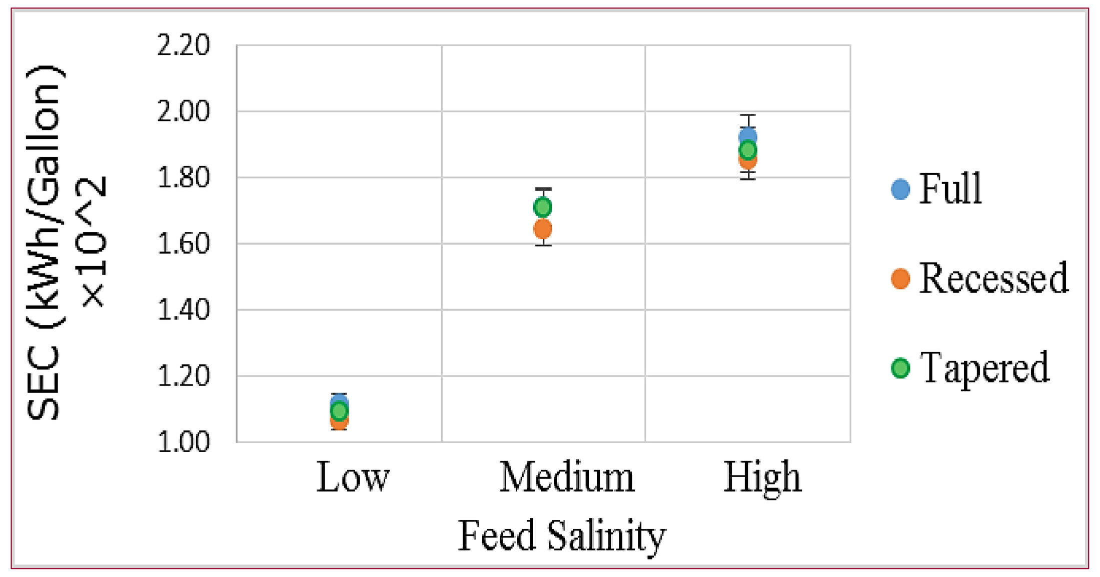

Figure 5. Effect of electrode design on specific energy consumption

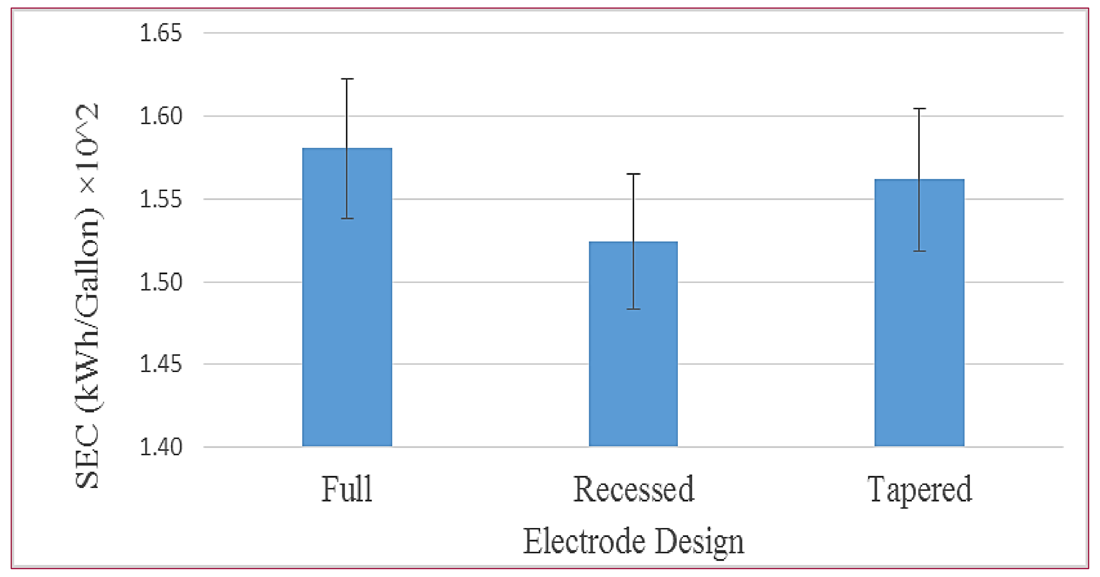

Figure 6. Effect of electrode design on specific energy consumption

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