2022 Fall **ME HYU**
Physicochemical Hydrodynamics **Prof. Rhokyun Kwak**
IC-PBL Project **due November 30, 2022**

Electrodialysis (Textbook Section 6.2)

Electrodialysis (ED) is one of the membrane-based separation processes utilizing ion exchange membranes. Ideally, anion exchange membranes (AEM) conduct negative salts (anions) only, while cation exchange membranes (CEM) conduct positive salts (cations) only. With this ion selectivity, the juxtaposed AEM and CEM can remove salts from incoming salty water under an electric field. The concept of ED was first suggested in the early 20th century, but the modern ED system known today was developed only in 1950, along with the first production of synthetic ion exchange membranes (IEM). After installing the first commercial ED plant by Ionics, Inc. for Aramco (Saudi Arabia) in 1954, ED technology has achieved many improvements; for example, membrane fouling and scaling were significantly reduced by electrodialysis reversal, and the production of ultrapure water was achieved by electrodionization.

The common form of ED system is shown schematically in Fig. 1. Alternating cation and anion-selective membranes form narrow channels into which the saline water is passed. An electric field is applied transverse to the membranes, and under its action cations such as Na+ pass through the cation-selective membranes, and anions such as CI- pass through the anion-selective membranes. In the setup shown in Fig. 1, this reduces the salt content in the channel formed by the left pair of membranes (the dialysate channel) and increases it in the channel formed by the right pair of membranes (the brine channel). In practice, stacks are made up of many alternating dialysate and brine channels between one pair of electrodes xc employed. and a number of these stacks may be used in series to achieve the desired level of desalination.

The fundamental problems in ED fall into two major areas. The first of these includes the largely chemical problems associated with the membranes: their perm-selectivity. their resistivity. their susceptibility to deterioration and fouling. etc. At the time the method was conceived suitable membranes did not exist and it is this area that has to data that received the most attention. At the present time, the technology of ion-selective membranes is well-developed. The second class of problems arc of hydrodynamic origin and depend on the derailed flow phenomena in the system. In this category are the several effects which arise from concentration polarization near the membrane-fluid boundaries, and which are recognized to be of critical importance in system design. Polarization sets a limit to the usable current. It also gives rise to a low salt concentration and a high electric field near the membranes. which in turn may lead to membrane fouling. precipitate formation. and other effects deleterious to membrane life. This hydrodynamic area has received less attention and to date a self-consistent. rational theory for the hydrodynamic aspects of ED process is lacking.

The purpose of the IC-PBL project is to follow the attempt to develop a hydrodynamic theory of desalination by ED for steady laminar flow. In textbook (section 6.2) or in Sonin and Probstein (Desalination, 1968 (https://doi.org/10.1016/S0011-9164(00)80105-8)), drive i) ion concentration distribution (eq. 6.2.16 in textbook) and ii) the current-voltage relation in ED (eq. 6.2.20 in textbook).

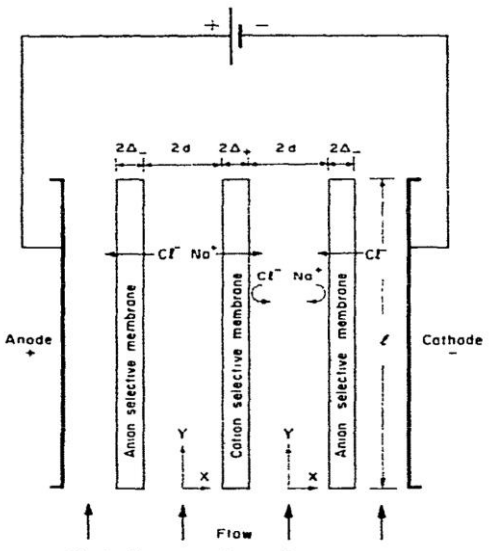


Fig. 1. System and coordinates.

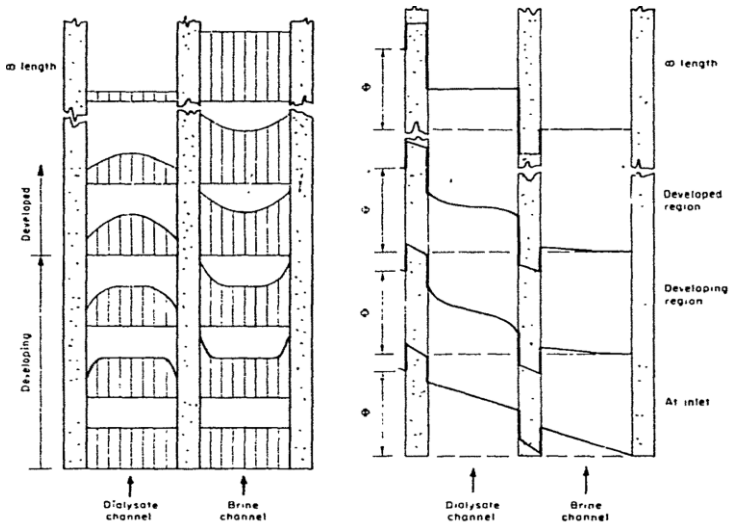


Fig. 2. Sketch of salt concentration distribution in channels.

Fig. 3. Sketch of potential distribution in channels.