Electrodialysis

Electrodialysis (ED) is used to desalinate or concentrate a liquid process stream containing salts. ED is a highly efficient method for separating and concentrating salts. It is also very useful to reduce salt contents of process streams with high amounts of salts.

Liquid process streams must be free of particles and high organic content, since ED is subject to membrane fouling. For this purpose, Electrodialysis Reversal (EDR) is a possible solution. EDR is operated like ED, but when fouling has build to a certain level, the setup is altered by reversing the direction of the constant current driving the separation and switching the dilution and concentration chambers. This way, it is possible to prolong the ED operation without having to stop and clean the equipment.

ED is very useful for water treatment: removal of mineral salts, sulfate, nitrate, etc. from brackish water and sea water. ED is also useful for waste water reduction or recovery.

Electrodialysis principle

Electrodialysis differs from pressure-driven membrane processes by utilizing electrical current as the main driving force in matter separation. This limits the possible solutes targeted for recovery separation to charged particles. The charged particles must be mobile, and the separation media must be able to transfer the electrical current with relatively low resistance. Electrodialysis is almost exclusively carried out on liquids.

The principle of electrodialysis is related to electrolysis as shown in figure 1.


Figure 1. Left side demonstrates a standard electrolysis process. Right side demonstrates the same process when ion-selective membranes are inserted.
CEM = cation-exchange membrane. AEM = anion-exchange membrane.

When utilizing **ion-exchange membranes** to prevent the migrating cations and anions from reaching the electrodes, where often unwanted electrode processes occur, new possibilities for separation arises. The ion-exchange membranes can be employed to concentrate process streams, separate ionic species from non-ionic species, or recover or extract charged solutes from waste streams. One example is the removal of salts

from seawater or brackish water. In geographic areas where water sources are scarce, electrodialysis is utilized as a pre-treatment to purify drinking water. Other places, the process concentrates seawater for a more economical production of table salt.

The standard configuration of a desalting process utilizing the electrodialysis principle is shown in figure 2.
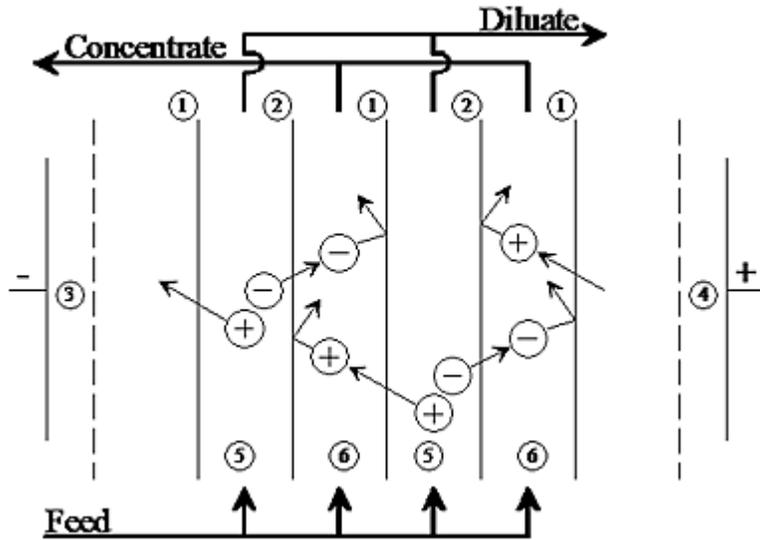
Figure 2. Principle of simple electrodialysis process. Diagram shows the membrane configuration with alternating cation-selective (1)and anion-selective (2) membranes between two electrodes ((3) and (4)), one at each end of the stack.

The drawing shows a membrane configuration with alternating cation-selective (1)and anion-selective (2) membranes. A cation-selective membrane (cation-exchange membrane) permits only positive ions to migrate through it. An anion-selective membrane (anion-exchange membrane) permits only passage to negatively charged ions. At each end of the membrane stack, electrodes (a cathode (3) and an anode (4)) are placed, supplying a well distributed electrical field of direct current across the membrane stack. Between every membrane, spacers are placed. Spacers make sure that there is room between membranes for the liquid process streams to flow along the membrane surfaces.
A special, conductive solution is added to each electrode chamber, where electrode processes are taking place. Usually, an electrode solution that does not result in unwanted reaction products is utilized for this purpose. A sulfuric solution as "electrode rinse" splits water molecules into hydrogen gas at the cathode (3) and oxygen gas at the anode (4).

For a simple desalting process, feed is entered into the flow channels and directed into the spacers. The electrical current influences the charged ions in the feed solution, and similar to ordinary electrolysis, cations are carried towards the cathode, while anions are carried towards the anode. The cations in every second spacer (5) are able to migrate through the cation-selective membrane (1)into the next spacers flow

chamber (6). In these flow chambers (6), the cations are trapped, unable to migrate through the anion-selective membrane (2). The anions in the flow chambers (5) are able to migrate towards the anode through the anion-selective membrane (2) and into the alternating flow chambers (6). In hese flow chambers (6), the anions are trapped, unable to migrate further, since they are faced with a cation-selective membrane (1). The two electrodes are kept separated from the processed solutions.

Thus, cations and anions are migrating out of every second flow chamber (5) into the remaining chambers (6). The result is that by collecting the outlet of the flow chambers (5) and (6) separately, a depleted and an enriched solution is created. This setup is common for concentrating seawater for table salt production or as pre-treatment for desalting brackish water to create drinking water.

A repeating section of the electrodialysis stack is named a cell pair. In the example of Figure 1.4, the cell pair consists of one cation-exchange membrane (1), anion-exchange membrane (2), one dilution chamber (5), and one concentration chamber (6). In commercial electrodialysis stacks, many hundred cell pairs can be stacked between one set of electrodes, thus improving energy efficiency and negating the electrode effects to great extent.