

Waste Water Brine Purification through Electrodialysis Ion Exchange

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Background

Reutilizing resources onboard the International Space Station (ISS) and for future deep space missions are critical for mission longevity and sustainability. Waste water brine produced from water recovery systems contain chemical species that could be processed into a potential fertilizer for future plant systems.

Fertilizer production can be achieved through a process called electrodialysis ion exchange. Waste water containing inorganic salt components are fed through a series of ion exchange membranes to produce fertilizer (a phosphate rich stream), electrolysis-grade water, and other useful commodities.

A test bed was constructed to conduct controlled experiments and an experimental design procedure developed to determine the feasibility of the process. Conductivity and pH probes were utilized to determine the ion concentration in each of the product streams, along with ion chromatography (IC) to define the exact concentration of each ion in every stream throughout the experiment. This is crucial in order to convey the effectiveness of ion removal from the incoming waste water stream.

The waste water and electrolyte streams were prepared in the lab prior to experimentation. Additionally, the ion exchange membrane configurations were developed and Opto 22 data analysis software incorporated to conduct measurements in real time.

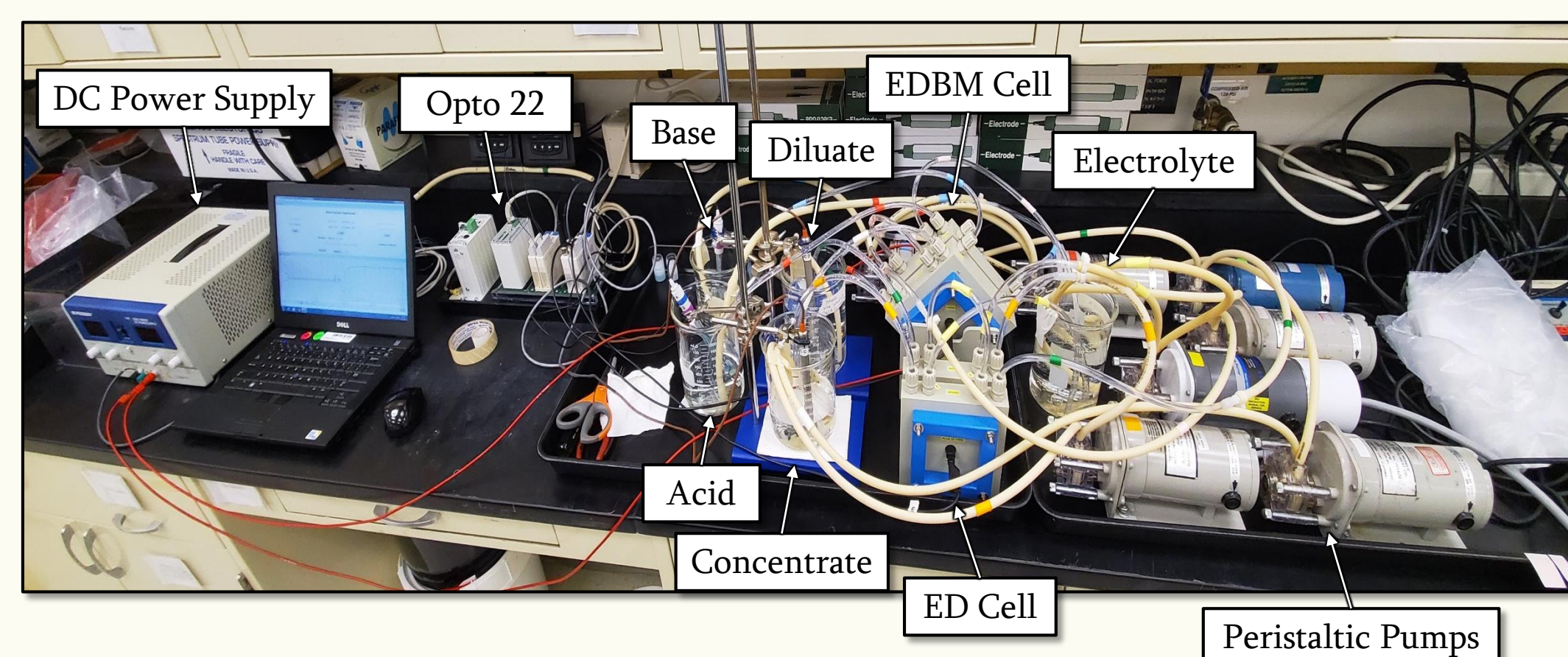
Methodology

Waste Water/Electrolyte Solution Preparation

- Simulated waste water brine was prepared according to the JSC inorganic urine hybrid ersatz formula containing sodium, potassium, magnesium, calcium, ammonium, chloride, sulfate, and phosphate ions.
- 0.25 M Na₂SO₄ was prepared as the electrolyte (EL) solution.

Ion Exchange Membrane Testing

- Electrodialysis cells 64002 and 64004 from PCCell GmbH:
 - ED 64002 – standard electrodialysis (ED) with polarity reversal (EDR) cell
 - ED 64004 – electrodialysis bipolar membrane (EDBM) cell
- Three sets of experiments were completed:
 - Standard ED, EDBM, & combined ED/EDBM set-up



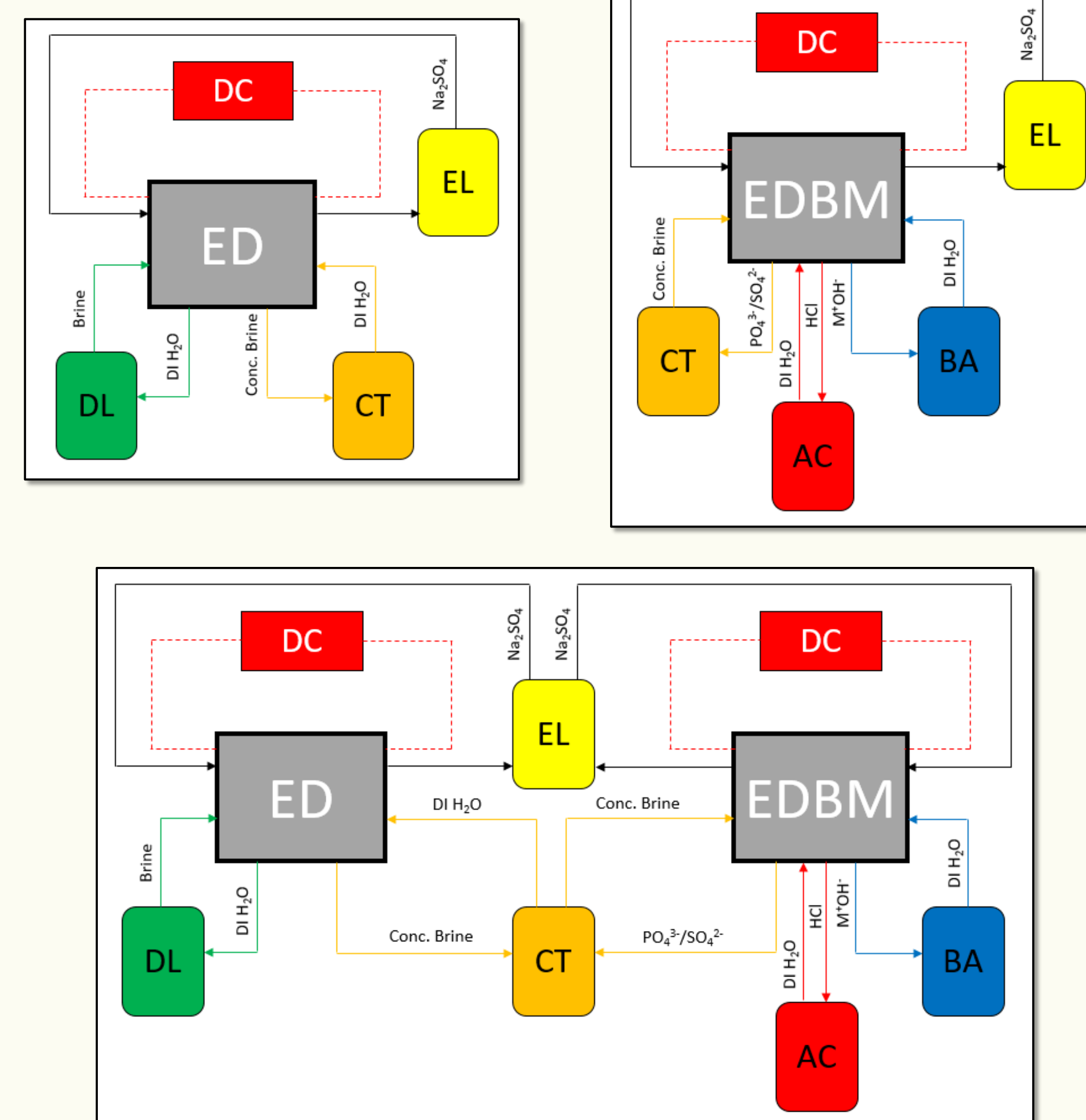
- The above image shows the combined ED/EDBM set-up in the lab.

Data Analysis

- 1 mL samples were taken from each stream for IC analysis at specified intervals throughout each run.
- Continuous data readings for conductivity, pH, and current were recorded using Opto 22 throughout the duration of each run.

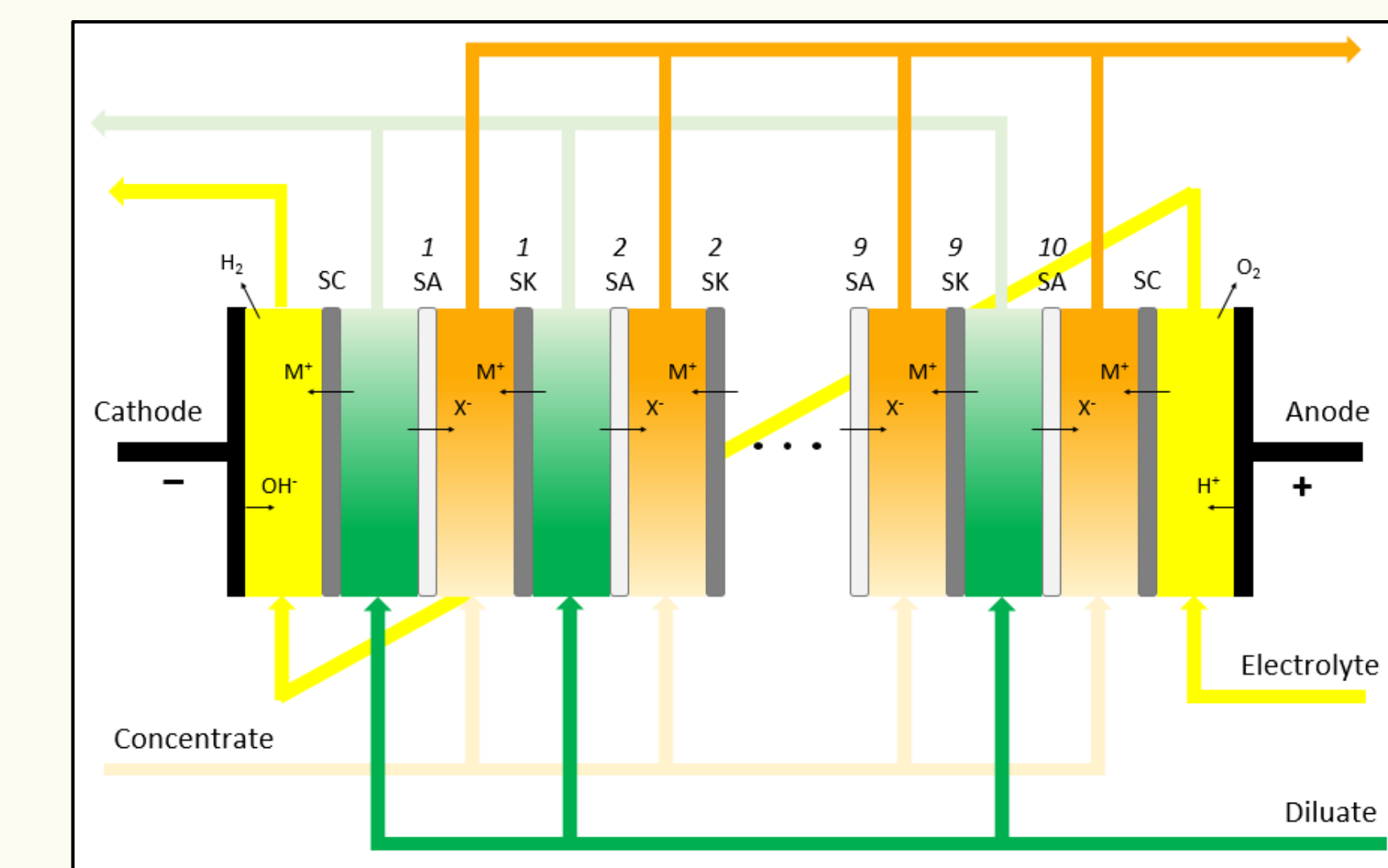
Schematics

Process flow diagrams for waste water purification and fertilizer production are shown below. Ions diffuse from the diluate (DL), which initially contains the waste water brine, to the concentrate (CT). The acid (AC) stream contains anions and hydrogen ions, while cations and hydroxides accumulate in the base (BA) stream. In theory, phosphate and sulfate ions will remain in the concentrate.



Membrane Configurations

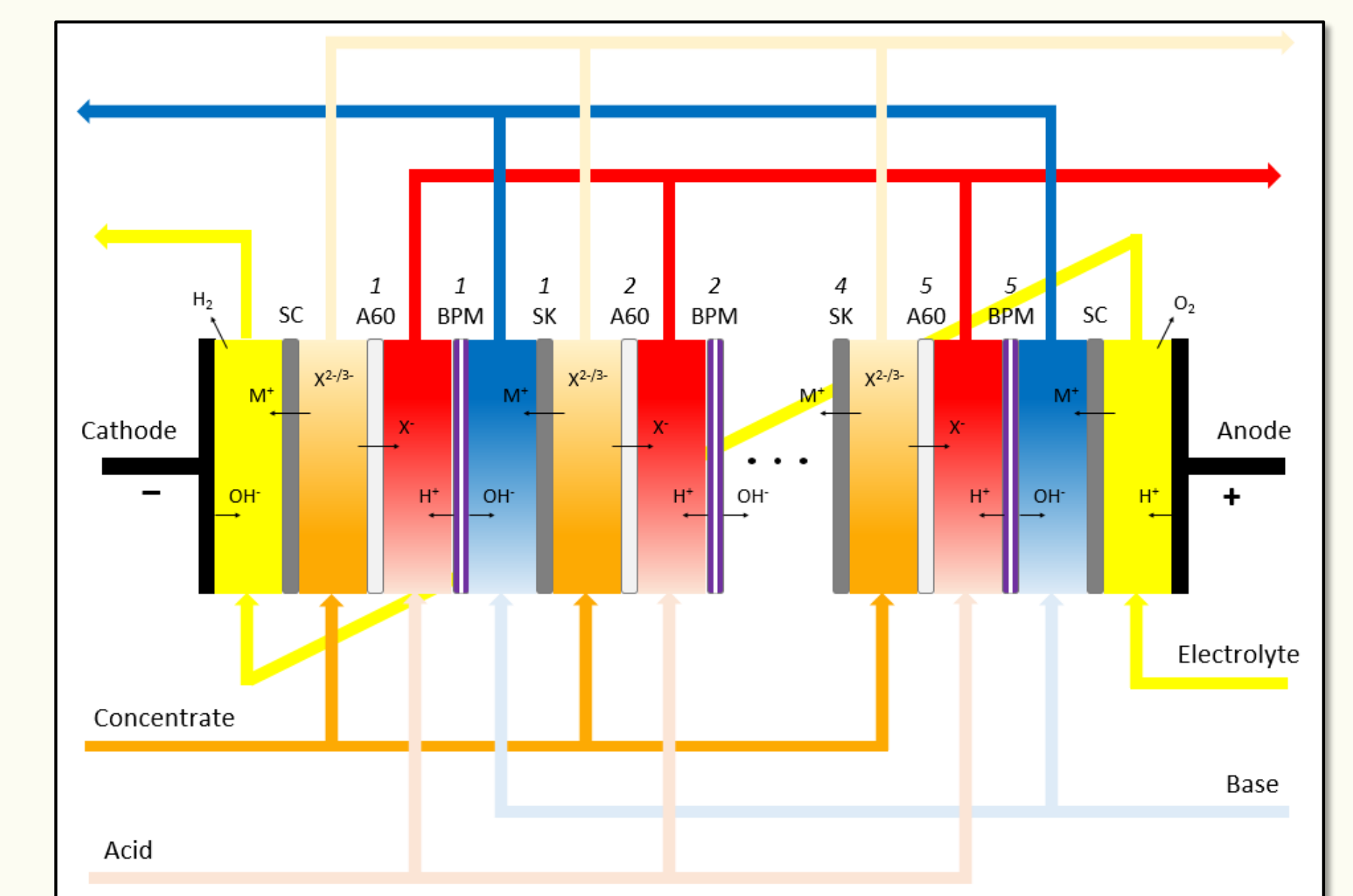
Anions diffuse towards the anode across the anion exchange membranes (SA), and cations towards the cathode across the cation exchange membranes (SK). The end cation exchange membranes (SC) are manufactured to withstand the pressures exerted by the electrolyte.



ED 64002 cell membrane set-up

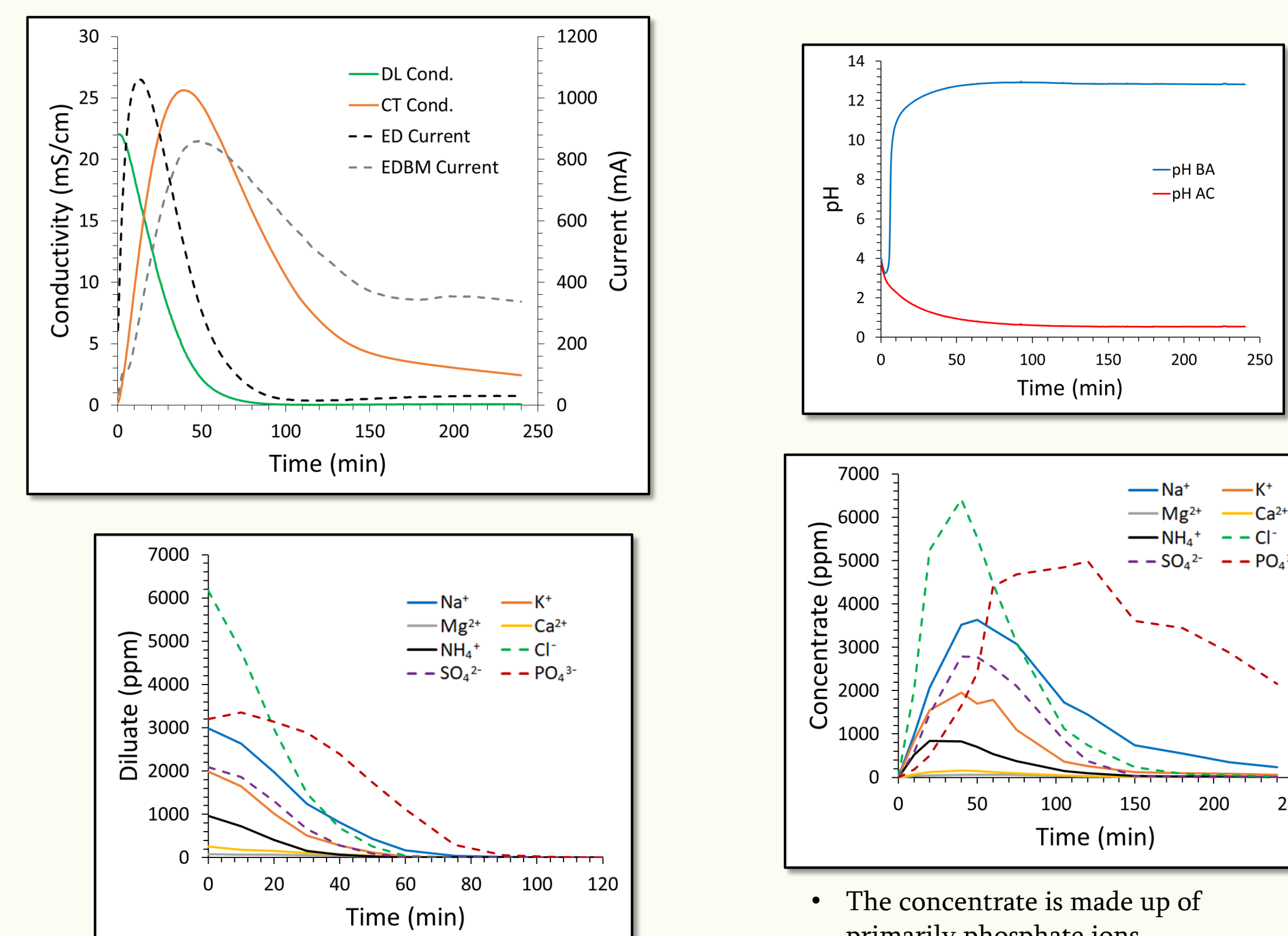
Monovalent anion exchange membranes (A60) in theory only allow anions with a valence of 1 to diffuse across. The bipolar membranes (BPM) contain both an anion and cation exchange layer. Hydrogen ions diffuse into the acid stream, and hydroxyl ions into the base.

ED 64004 cell membrane set-up



Results

The conductivity of the diluate decreases to that of potable water within 2 hours, while that in the concentrate increases. Monovalent anions and cations diffuse from the concentrate to the acid and base respectively, thereby ultimately decreasing the conductivity.



• The concentrate is made up of primarily phosphate ions.

Conclusions

Ions successfully diffused across their respective membranes into the concentrate, acid, and base streams. This resulted in pure water (DL), a phosphate rich stream (CT), and a separate anion/hydrogen (AC) and cation/hydroxide (BA) stream. However, sulfate and some phosphate ions were able to diffuse through the monovalent anion exchange membrane into the acid stream. This resulted in predominantly phosphate ions remaining in the concentrate.

Optimization of the process will be accomplished by altering flowrates of each stream and initial volumes, adjusting the power input and resulting current through each cell, and varying the starting parameters of each system.

References

- Anthony, S., Jolley, S., Captain, J., Pawate, A., & Kenis, P. "Advanced Water Purification System for In Situ Resource Utilization." *AIAA SPACE Forum*. San Diego, CA. September 10-12, 2013.
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