Wastewater Brine Purification and Recovery through Electrodialysis Ion Exchange

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Exploration Research and Technology Programs

Background

- Reutilizing resources onboard the International Space Station (ISS) and for future deep space missions are critical for mission longevity and sustainability.
- Wastewater brine produced from water recovery systems contain chemical species that could be processed into a potential fertilizer for future plant systems.
  - This can be achieved through a process called electrodialysis ion exchange.
- Wastewater 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.

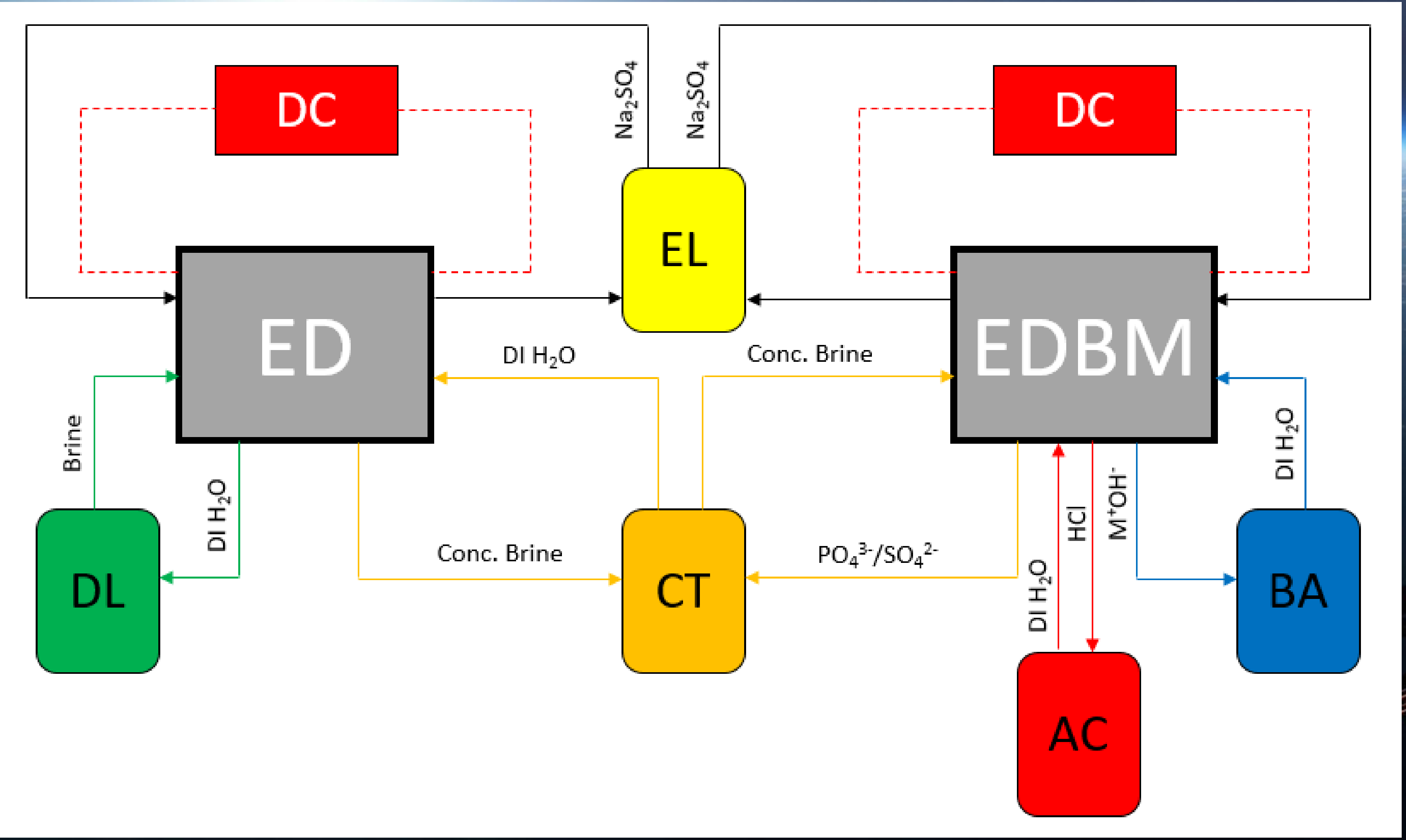
Electrodialysis Cells

- Electrodialysis cells consisting of anion and cation exchange membranes, monovalent anion exchange membranes, and bipolar membranes were utilized to achieve selective ion exchange.
- The use of the electrodialysis cells were effective for both water extraction and ion separation.
  - Ions successfully diffused across their respective membranes into the concentrate, acid, and base streams.
  - This resulted in pure water, a phosphate rich stream, and a separate anion/hydrogen and cation/hydroxide stream.

Methodology

- Simulated wastewater brine was prepared according to the JSC inorganic urine hybrid ersatz formula containing sodium, potassium, magnesium, calcium, ammonium, chloride, sulfate, and phosphate ions.
- Electrodialysis 64002 and 64004 from PCCell GmbH:
  - ED 64002 – standard electrodialysis (ED) with polarity reversal (EDR) cell
  - ED 64004 – electrodialysis bipolar membrane (EDBM) cell
- Data Analysis:
  - 1 mL samples were taken from each stream for IC analysis at specified intervals.
  - Continuous data readings for conductivity, pH, and current were recorded using Opto 22 throughout the duration of each run.

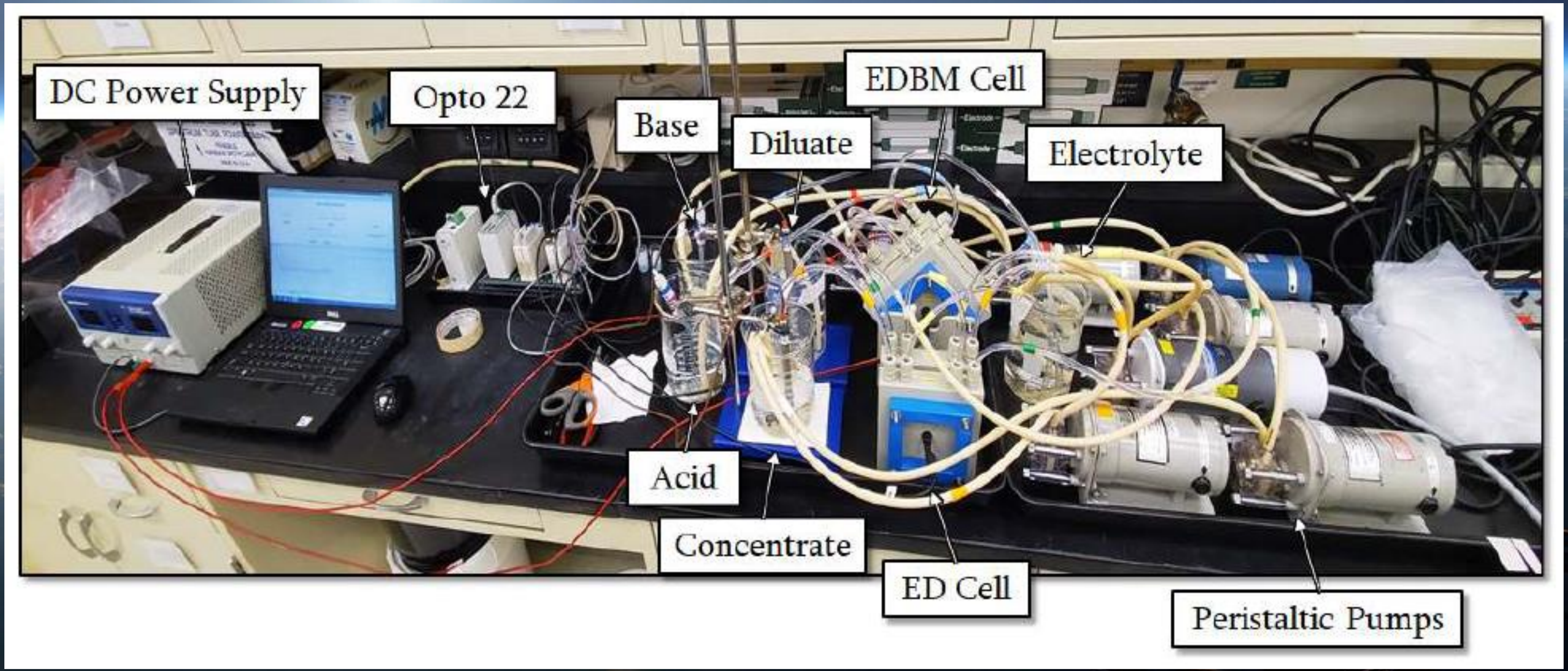
Schematic


DC
DC
Na_2SO_4
Na_2SO_4
EL
ED
EDBM
DI H_2O
Conc. Brine
Brine
DI H_2O
Conc. Brine
PO_4^{3-}/SO_4^{2-}
DI H_2O
HCl
M^+OH^-
DI H_2O
DL
CT
BA
AC

Schematic Description

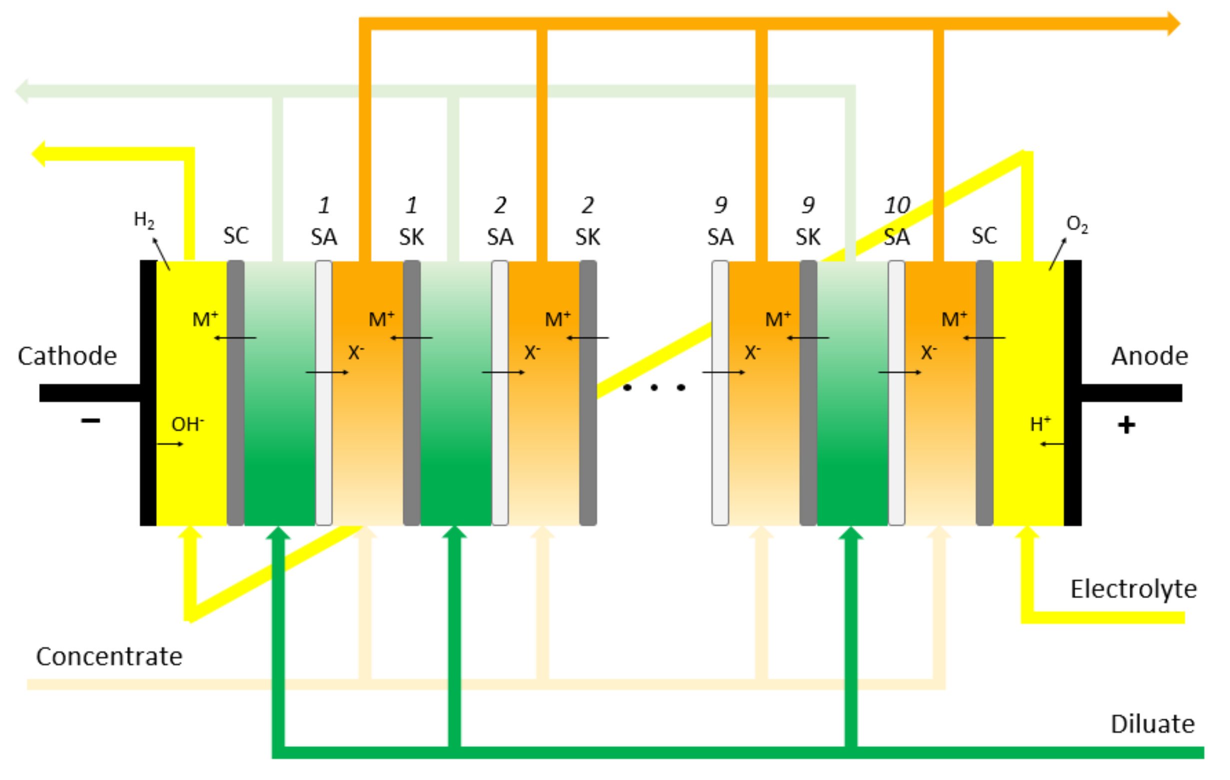
- Process flow diagram for wastewater purification and fertilizer production.
- Ions diffuse from the diluate (DL), which initially contains the wastewater brine, to the concentrate (CT).
- The acid (AC) stream contains anions and hydrogen ions, while cations and hydroxides accumulate in the base (BA)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

Test Set-up

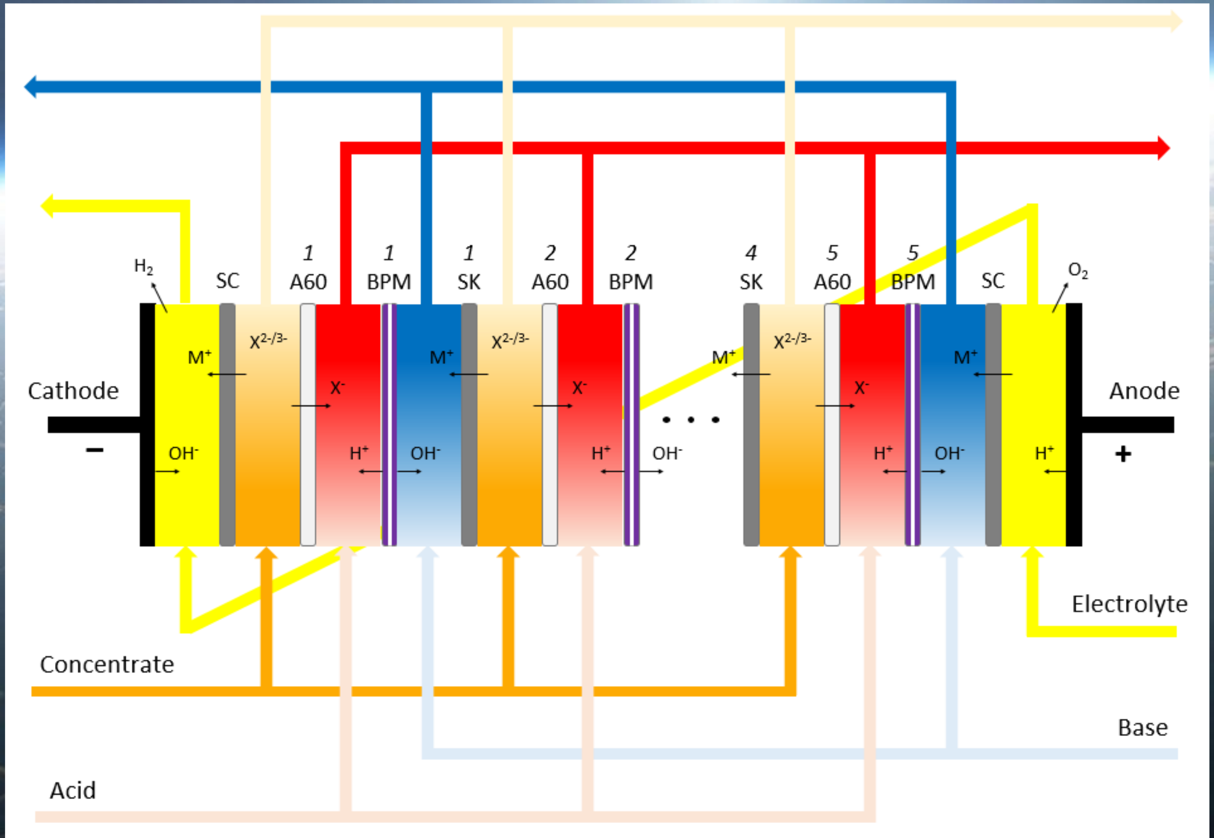

DC Power Supply
Opto 22
Base
Diluate
EDBM Cell
Electrolyte
Acid
Concentrate
ED Cell
Peristaltic Pumps

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 the withstand the pressures exerted by the electrolyte.
- The figure to the right represents the ED 64002 set-up.



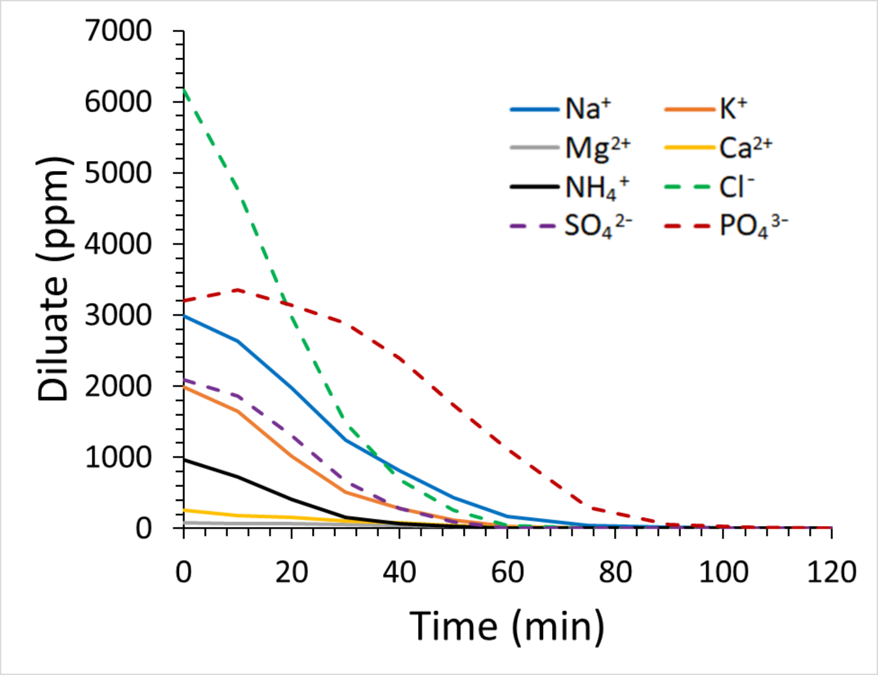
Membrane Configurations (cont.)

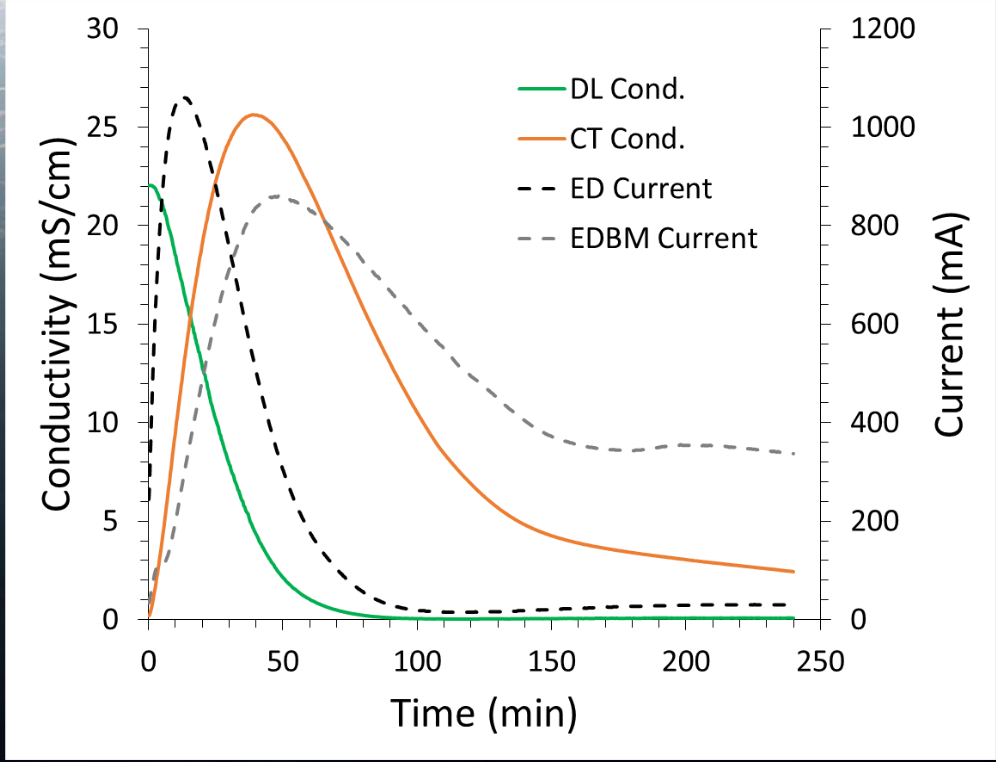


- Monovalent anion exchange membranes (A60) in theory only allow anions with a valence of 1 to diffuse across.
- The bipolar membranes (BPM) contain both an anion and cation exchange layer.
- Hydrogen ions diffuse into the acid stream, and hydroxyl into the base.
- The figure on the left represents the ED 64004 set-up.

Results

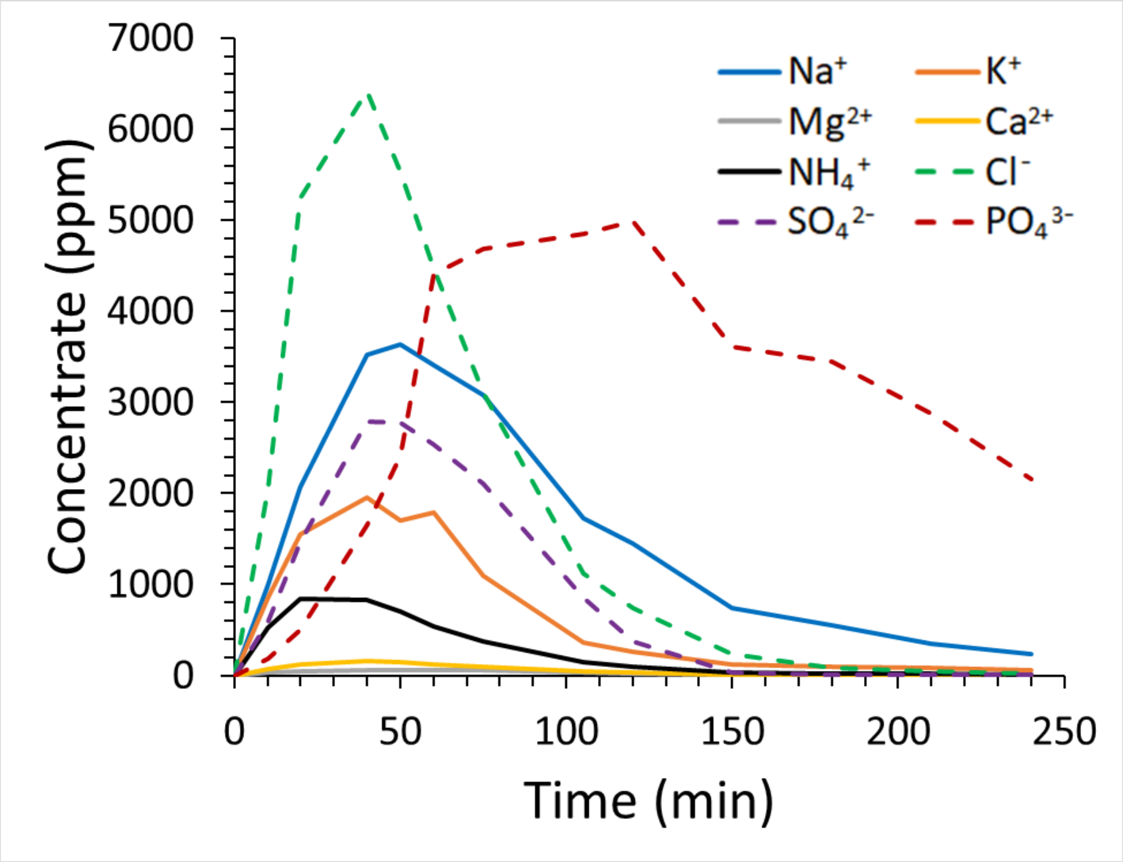
- The conductivity of the diluate decrease to that of potable water within 2 hours, while that in the concentrate increases. Monovalent anions and cations diffuse from the concentrate to the acid and base respectively, thereby ultimately decreasing the conductivity.

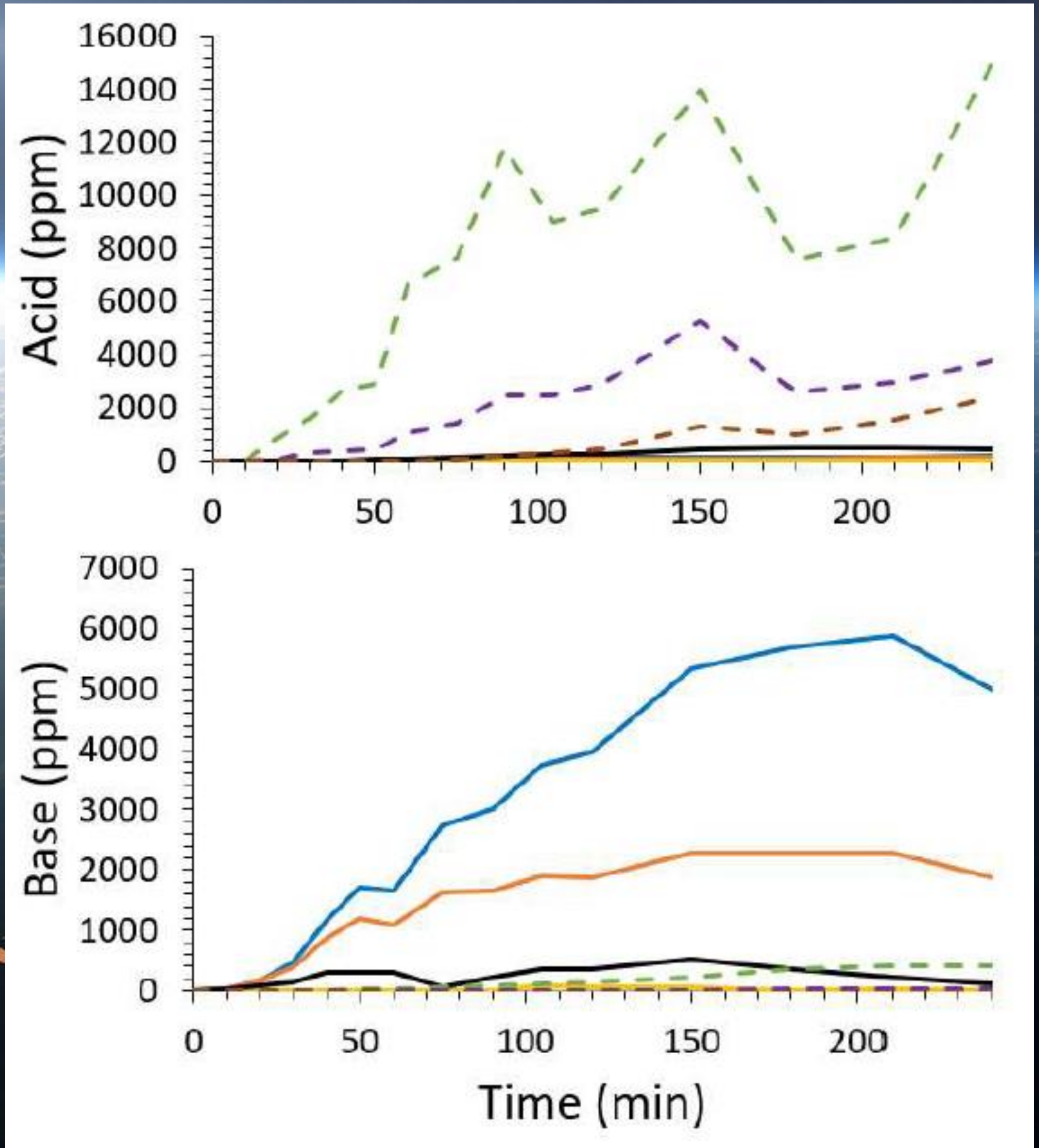




Results (cont.)

- The concentrate is made up of primarily phosphate ions.





Optimization Testing

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

	Voltage	Initial Volumes (mL)					Flowrates (L/min)				
ID	(V)	DL	CT	AC	BA	EL	DL	CT	AC	BA	EL
S1	10	1000	500	500	500	1000	½	½	½	½	1
S2	10	1000	500	500	500	1000	¼	¼	¼	¼	1
S3	10	1000*	-	0	0	1000	½	½	0	0	1
S4	10	1000	250	250	250	1000	½	½	½	½	1
S5	10	1000	250	250	250	1000	¼	¼	¼	¼	1
S6	10	1000	1000	1000	1000	1000	¼	¼	¼	¼	1
S7	15	1000	500	500	500	1000	¼	¼	¼	¼	1
S8	5	1000	500	500	500	1000	¼	¼	¼	¼	1
S9	10	1000*	-	0	0	1000	¼	¼	0	0	1
S10	10	1000*	-	500	500	1000	¼	¼	¼	¼	1

Optimization Testing Takeaways

- The conductivity of the diluate decreased to that of potable water at a greater rate with the faster flowrate.
  - However, more power is ultimately required.
- Potable water can be produced at a quicker rate if the inorganic water was split evenly between the diluate and concentrate, initially.
  - On the other hand, only half the amount of potable water was produced per liter of inorganic waste.
- The cells still functioned properly when dropping the starting volumes.
  - While we didn’t reach it in this project, the volume can only be dropped until the solubility limit is reached.
- Increasing the power input to each cell drastically reduced the overall time.
  - At 15 V, the run was completed in 120 min, compared to 240 min at 10 V.
  - However, the upper voltage limit was nearly attained (2 V per cell pair).

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.
  - Resulting is predominately phosphate ions remaining in the concentrate.

Any Questions?

Thanks for listening!

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