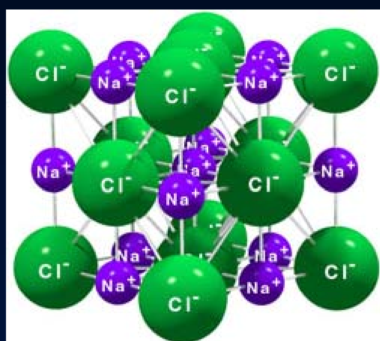
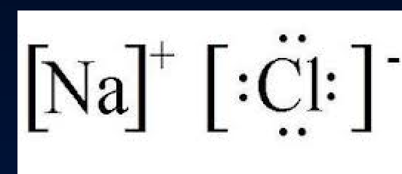
A Method for Removing Brine Spills in Soil Using Electrokinetics





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Current Remediation Technologies for Brine Spills

- Amend and/or Flush
  Protective of an aquifer ?
- Dig and Haul
- Cap
-

Electrokinetic Remediation ?

- Application of direct current (DC) electricity to the soil

- Polarized electrodes invoke movement of pore water and ions contained in the pore water, even in low permeability soils

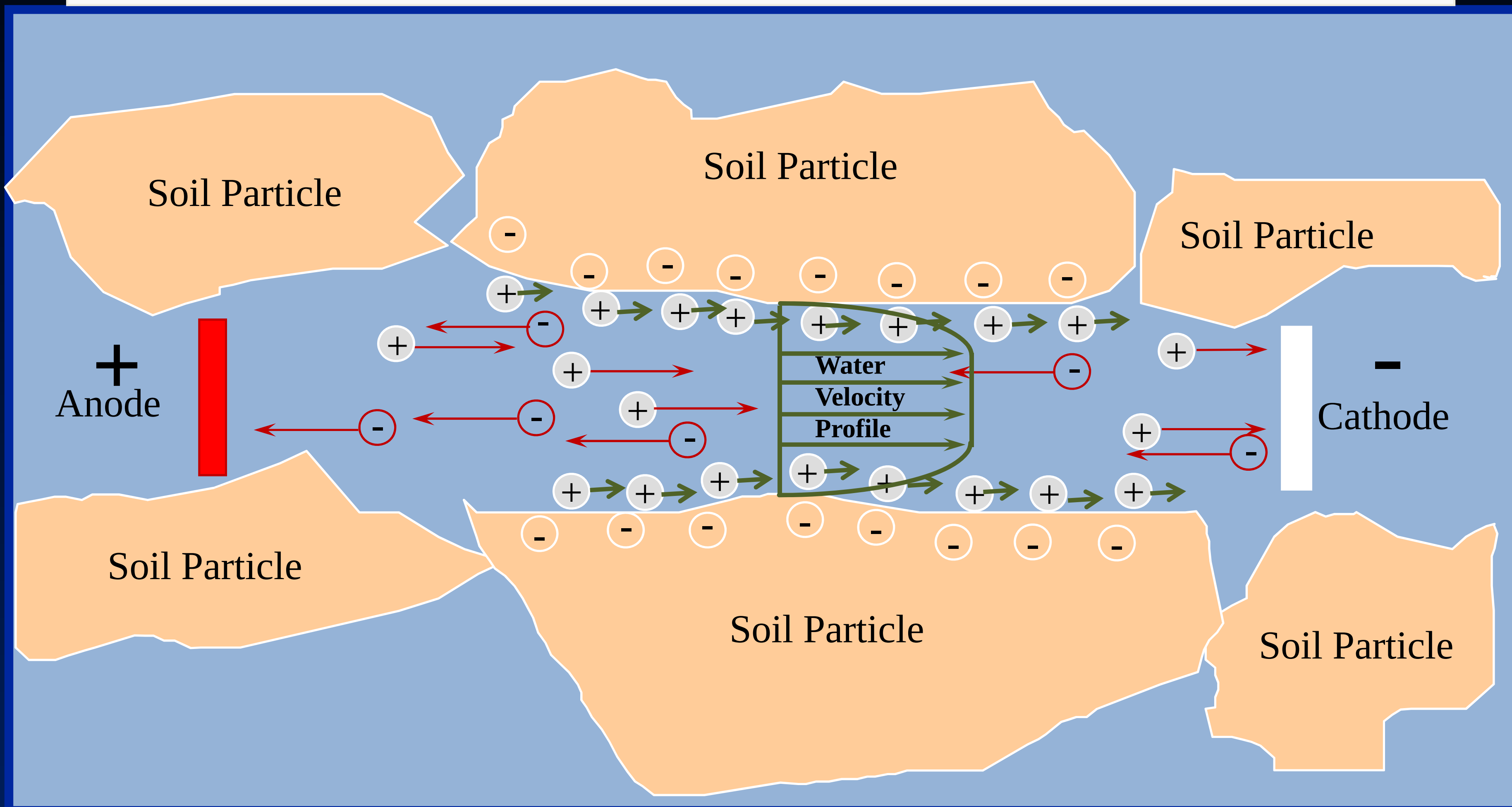
Electrokinetics

- Electroosmosis – Movement of pore water and contaminants toward the cathode

- Electromigration – Migration of ionic species toward respective electrodes (anions toward anode, cations toward cathode) by electrical attraction

Principles of Electrokinetics

Electroosmosis = Water Transport from anode to cathode
Electromigration = Ion Transport to the opposite electrode



Electrokinetic Applications

- Environmental Remediation
  - Heavy Metals (lead, chrome)
  - Organic Solvents (with in-situ ZVI)
  - Others (arsenic, nitrate, ISCO, bio-amendments)
- Dewatering/Stabilization
- Desalinization

- EK works in saturated & unsaturated zones

How EK Desalinization Works

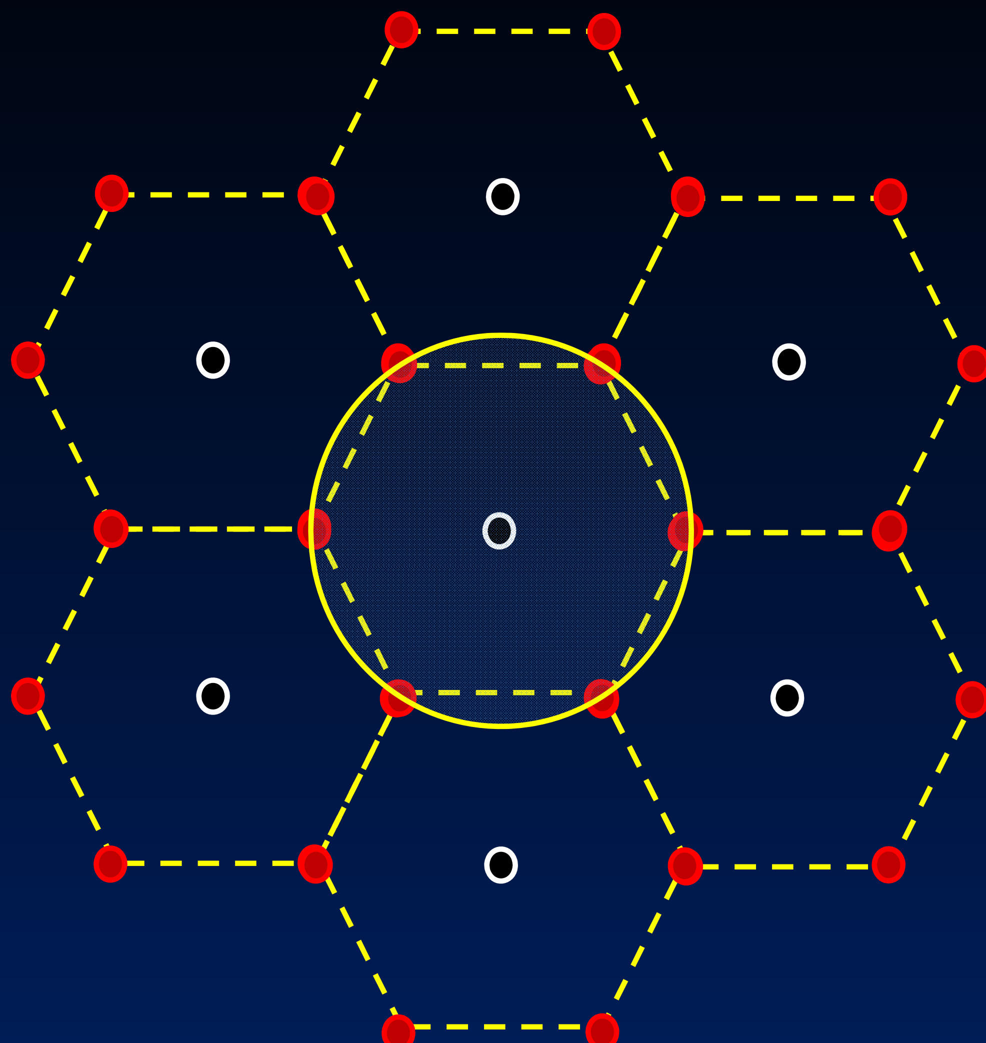
- Sodium ions migrate toward the cathode by electromigration and electroosmosis where they are removed
- Chloride ions migrate toward the anode by electromigration, where they are removed or oxidized to chorine
- The removed cathode and anode streams are combined as brine and disposed/injected or beneficially reused

Model Development

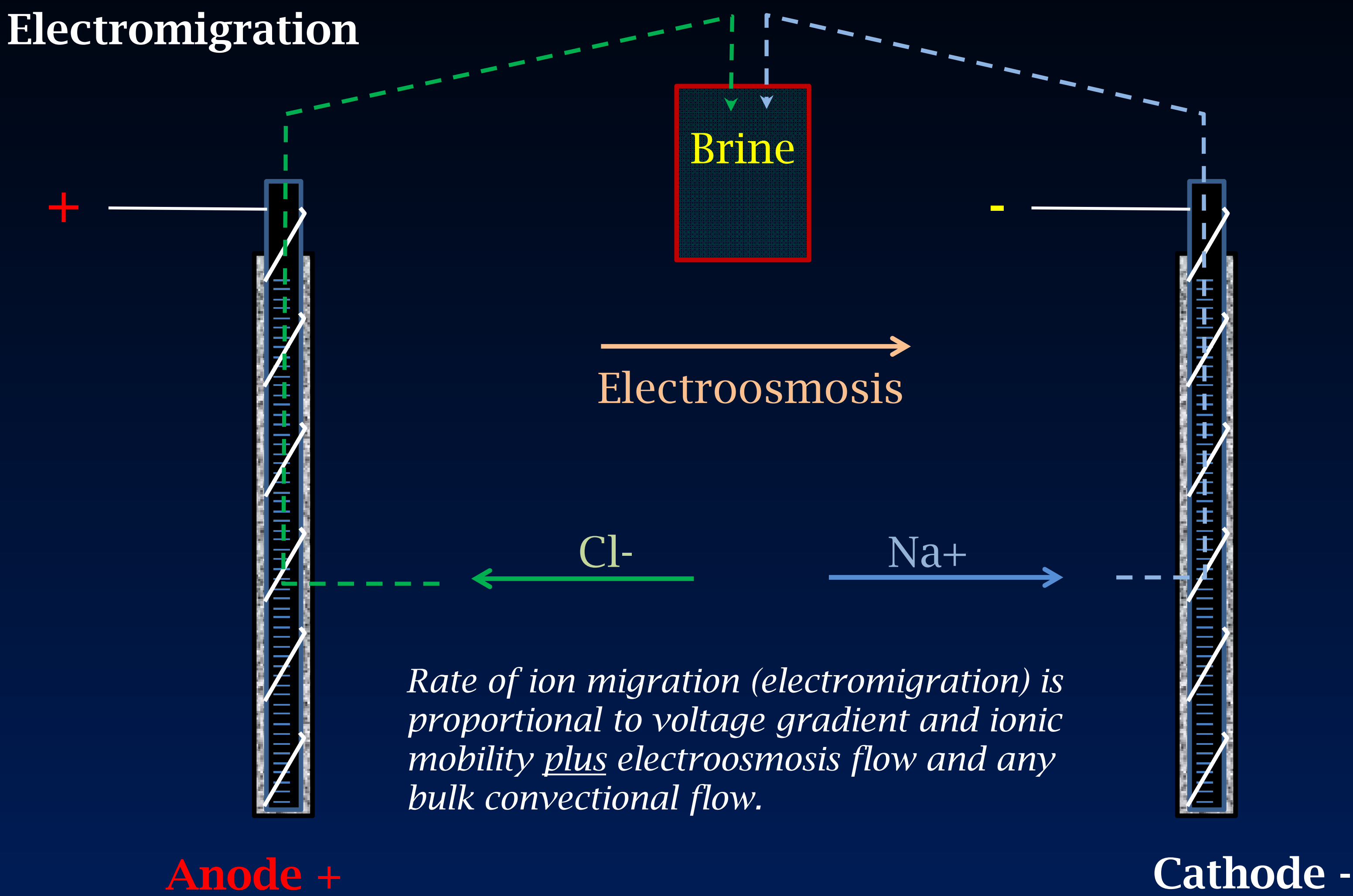
- Model developed to help develop appropriate installation and operation
  – 2-Dimensional
  – Cylindrical coordinates (cathode at center)
  – Zero flux boundary at anodes, C = 0 at cathodes
  – Estimates removal times based on electromigration + electroosmosis

Excel based model developed by Terran & Dr. Robert Wilkens at University of Dayton

Electrode Pattern

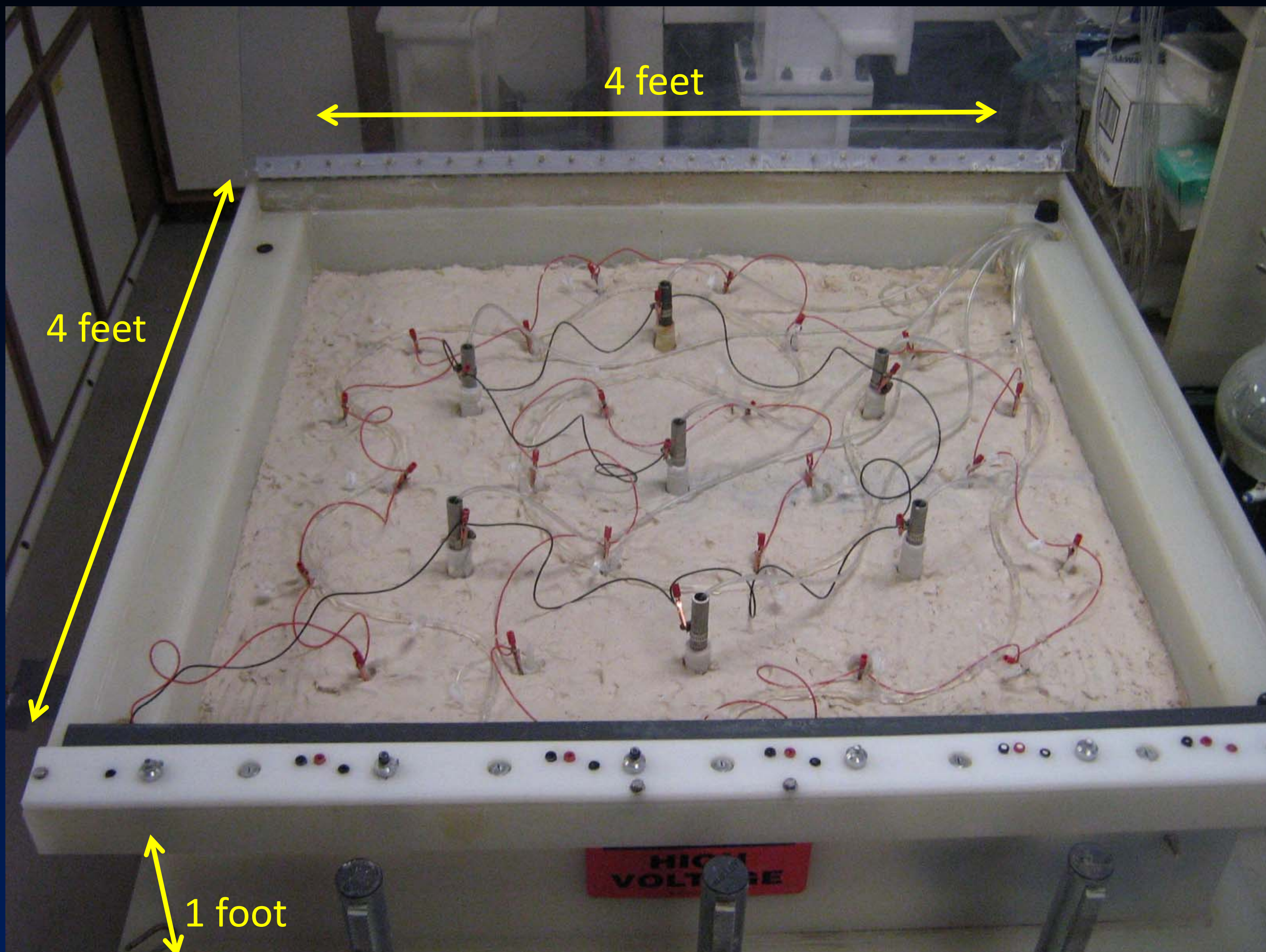


EK Desalinization Application



Rate of ion migration (electromigration) is proportional to voltage gradient and ionic mobility <u>plus</u> electroosmosis flow and any bulk convectional flow.

Pilot Test Work

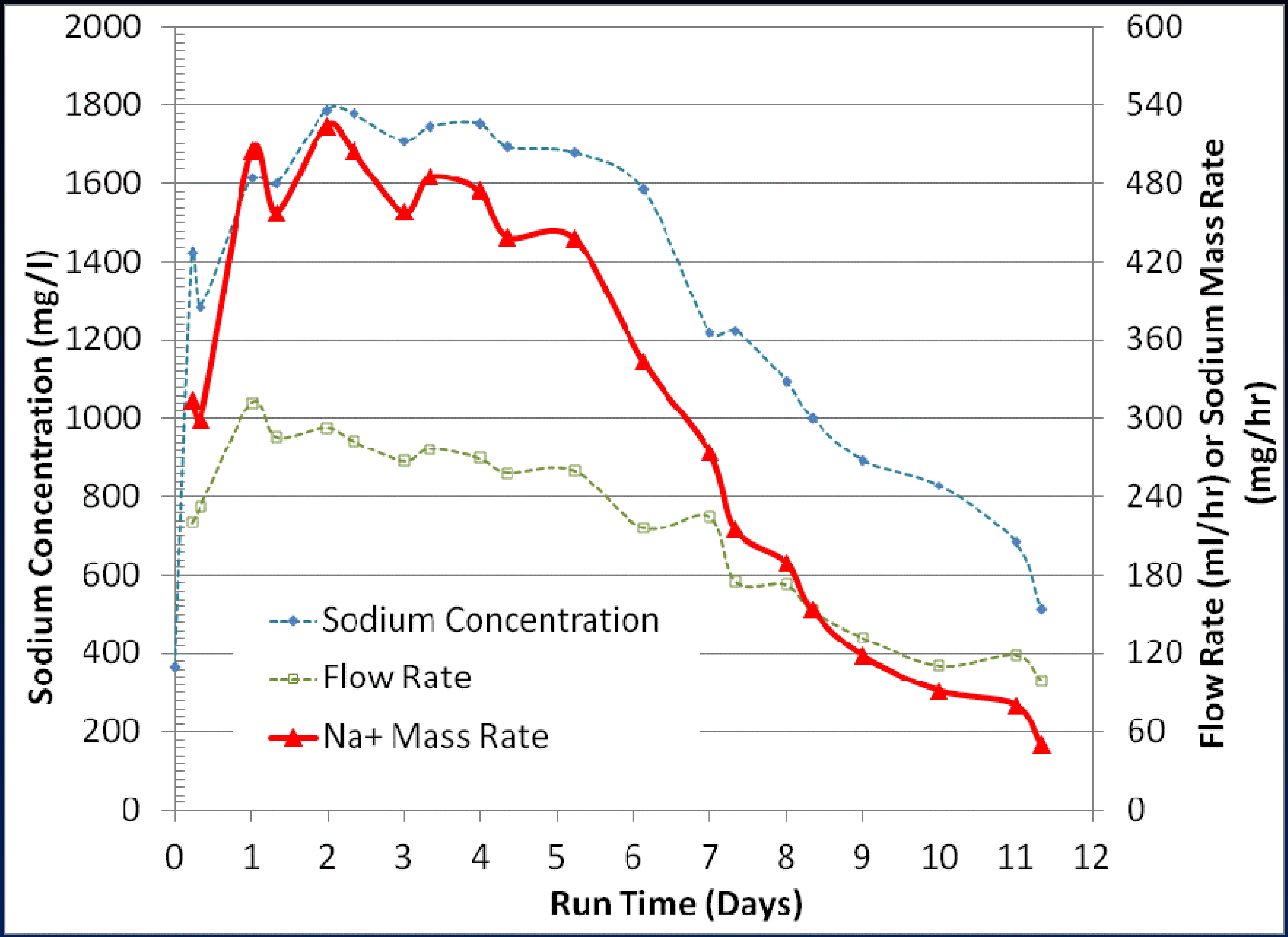


Sodium loading = 500 mg/kg, kaolin clay

Operations

- DC power supply @ 10 volts, 1.6 to 0.3 amps
- Anode – cathode spacing of 8 inches (~0.5 V/cm)
- Water supplied at anode to replace EO water
- EO water (+ sodium) removed at cathode
- Chloride accumulates and oxidizes to chlorine at anode
- Sodium was model compound (conservative tracer)
- Model predicted 4^{+} days to travel 8”
- Expected exponential decline as residuals bleed out

Sodium Trends



Soil Sampling

Periodic Sampling

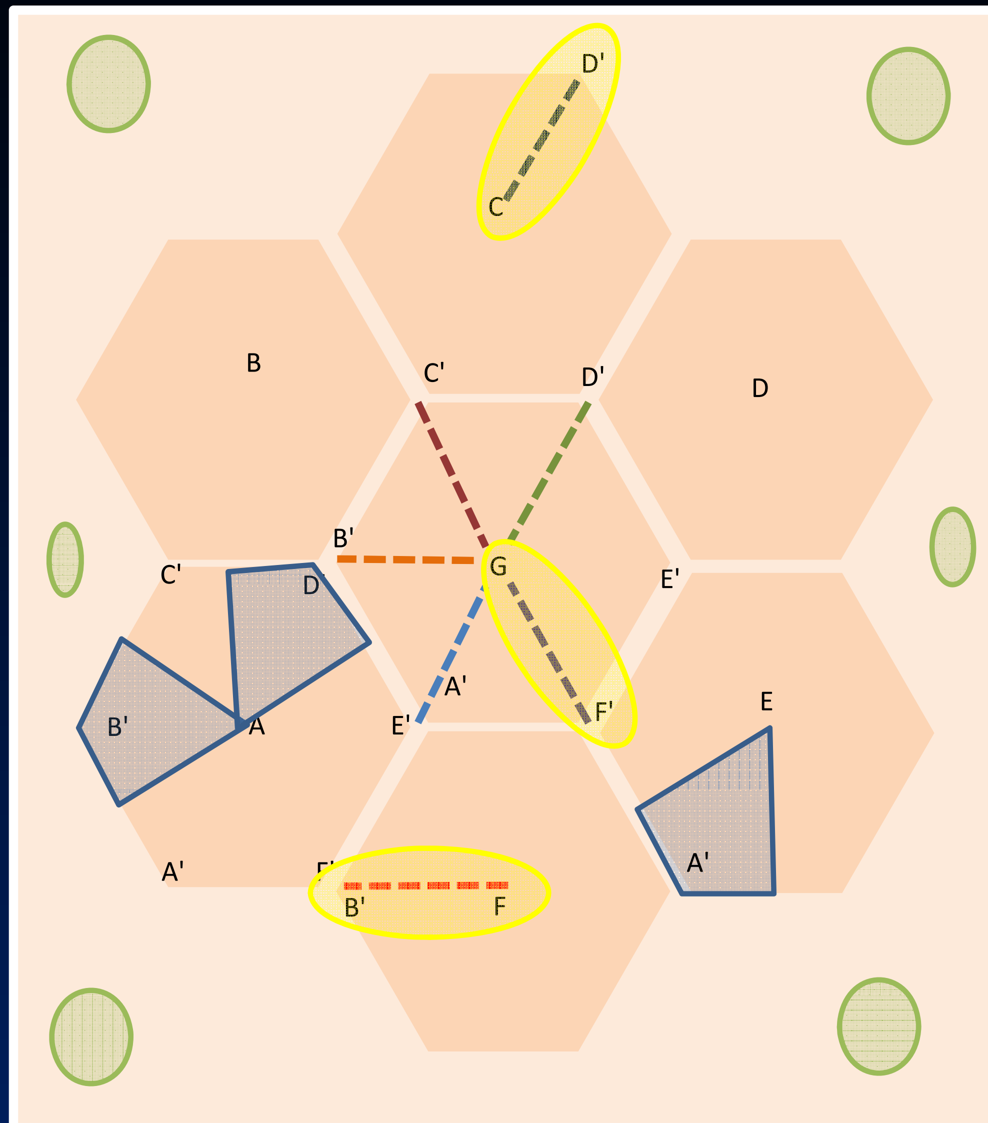
B' F

Radial Profile Samples (1,3,5,7" from anode)

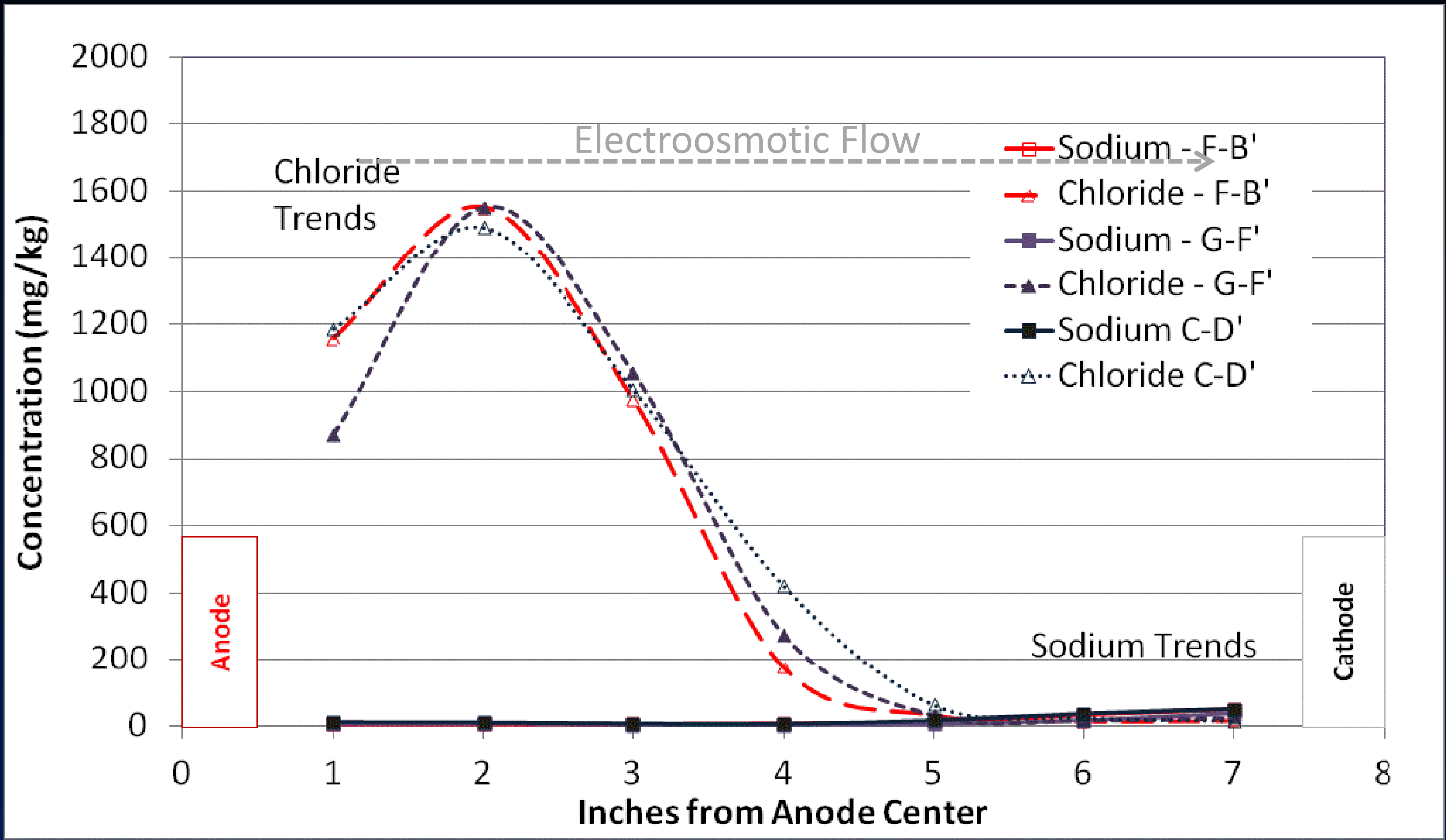
Final Sampling

Bulk Soil Samples

Background Sampling Areas



Soil Segment Profiles



Final bulk sampling results = 83% removal of sodium, 71% removal of chloride

Agricultural Field Soil

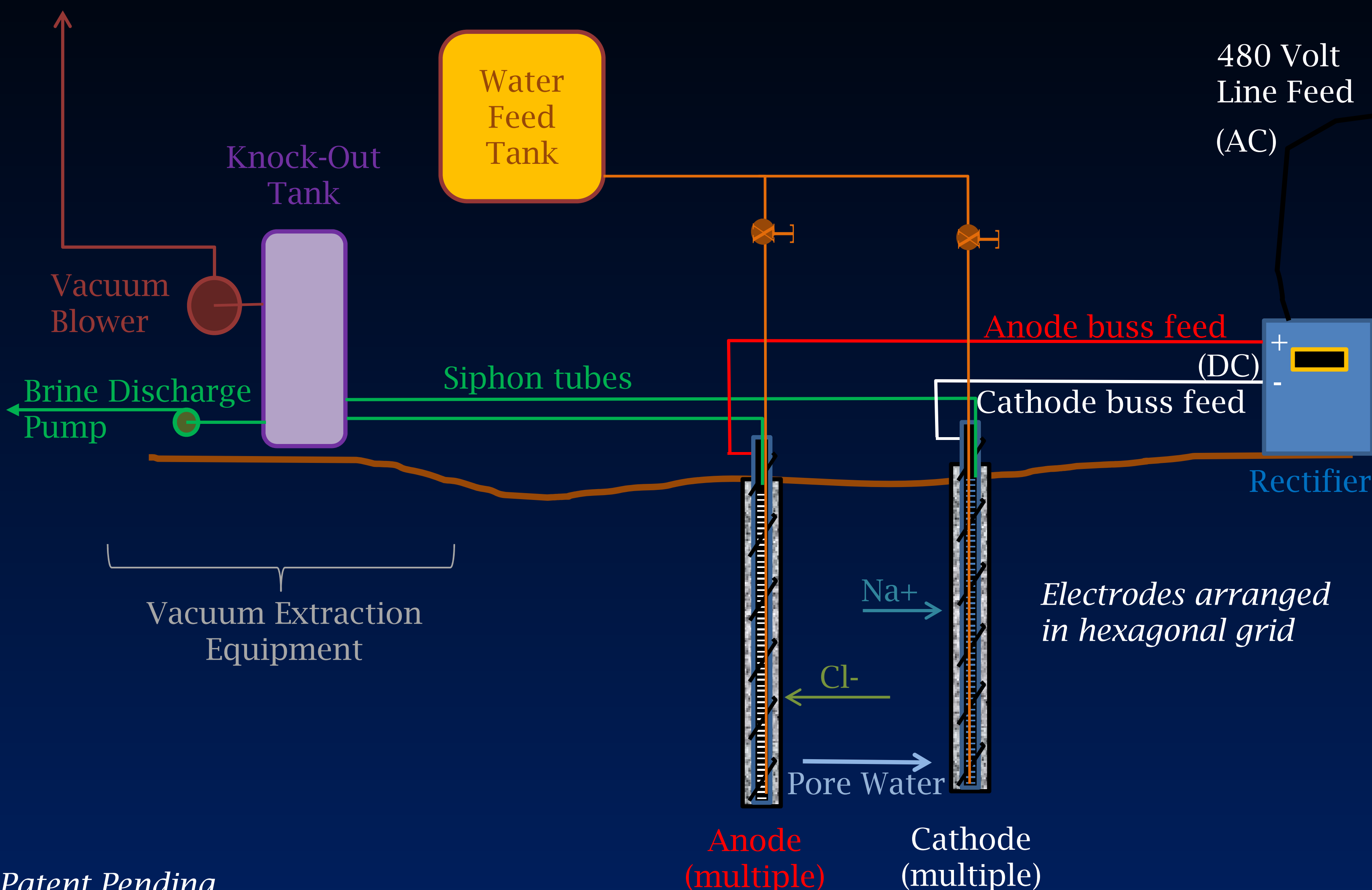
- Experiment was duplicated using a field soil from nearby farm (clay loam)
- Sodium migration was retarded by up to 50%
- Similar soil concentration profiles at end of test
- Bulk removal rates were slightly better than kaolin test but test was run longer
  - Kaolin test removed 83% sodium, 71% chloride
  - Ag soil test removed 84% sodium, 79% chloride

Complete data presented in *Journal of Hazardous, Toxic and Radiological Waste (January 2013, January 2014)*

Field Scale Design

- Readily available equipment and parts (lowest costs)
- Electrodes are installed like miniature wells.
  - Slotted 1 or 2-inch PVC well screen
  - DSA wire wrapping as primary electrode
  - Backfill annulus with cathodic backfill material (example-Loresco SWS®)
  - Installed with Geoprobe® or small drill rig
- Extraction equipment can be a small SVE package unit operated on a timer
- Passive as possible operation
- Tuned to minimize water usage

EK Desalinization Process



Patent Pending

Additional Options

- **Green Power**
  - DC rectifier can be supplemented or replaced by:
    - Solar
    - Wind
- **Re-use** of Brine for road treatment
  - In areas where road salt is used

Conclusions

- EK can be used to remove sodium and chloride from soil
- Costs may be competitive with hauling and landfilling

- Next step is field scale applications