## 2.1 Electro-Osmosis

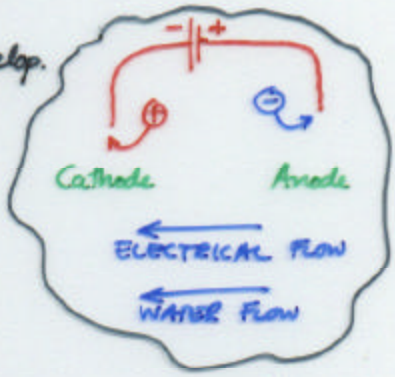
**Main mechanism:**
- Ionic migration of charged species (cations, anions) due to electrical potential
- Advection of neutrally charged species in the diffusive flow
- Osmotic and pH gradients may develop → reverse flows
- Desiccation due to electrode heat and soil fabric changes.

**Process**

Surplus of cations ⊕ ∴ net flow to cathode since more cations ⊕.
"Drag" water with them, net flow to cathode.

**Influencing Factors**

- Electrical and hydraulic gradients held constant but chemical gradients develop.
  - If these develop counter current then reverse flows due to advection.




- Electrode heating and pH changes.
  - Anode → pH 2
  - Cathode → pH 12

  } ∴ acid front propagation towards cathode

Alkaline conditions may → desorb organics, pesticides, heavy metals and enhance removal.

## Field Implementation

Apply electrodes and potential

Recover contaminants at electrodes (wells)

Dissolved contaminants pumped to surface → treated

Similar strategy to pump-and-treat using electrodes

eg. use high conductivity features etc.

Electrodes – e.g. Well casing (steel) @ injection & extraction wells.

Graphite electrodes – non wetting surfaces, corrosion resistance, reduce hydrogen gas formation.

Prevent consolidation @ anode and keep saturated by adding surfactants, salts and water

Dewatering application.
Contaminant removal

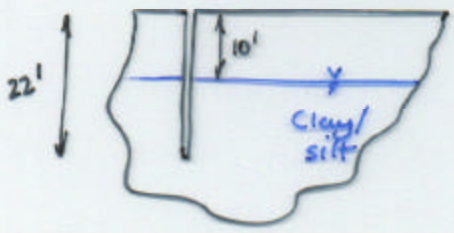
Electrode spacing 30 ft
3-5 ft
} DC potential 25-500 V.

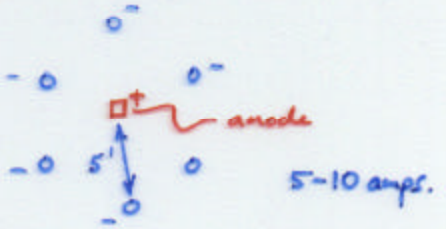
## Demonstration level

Clay dewatering / landslide stabilization 1930s +

Only lab studies for organics such as TCE

Field studies: Chrome plating plant, Corvallis, Oregon.




Chrome conc: 1000 mg/L → 35 mg/L

Also applied to: lead, arsenic, acetic acid. Bench studies for TCE.

## Applicability / Limitations

- Ionic species, radionuclides, heavy metals, polar organic compounds
- Fine grained soils with large clay content
- Desaturation, drying, desiccation } may effect efficiency
- Gas production & electrode corrosion }

## Cost and Availability

- Full scale. Geotech. and contaminant removal
  - Well established design criteria
    European patent - Geokinetics
    US Patent (1991) Probstein
  - No DNAPL field scale study (non-polar)

Long term treatment → $50/ton
Short term $400/ton } electricity $2 - $20/ton.

of remediated fine grained soils

| Flow $J$ | Gradient $X$ | | | |
|---|---|---|---|---|
| | Hydraulic Head | Temperature | Electrical | Chemical |
| Fluid | Hydraulic conduction: Darcy's law | Thermo-osmosis | Electro-osmosis | Chemical-osmosis |
| Heat | Isothermal heat transfer | Thermal conduction: Fourier's law | Peltier effect | Dufour effect |
| Current | Streaming current | Thermo-electricity: Seebeck effect | Electrical conduction: Ohm's law | Diffusion and membrane potentials |
| Ion | Streaming current | Thermal diffusion of electrolyte: Soret effect | Electrophoresis | Diffusion: Fick's law |