Electrochemical techniques for water treatment and valuable recovery

Anne Benneker, Assistant Professor anne.benneker@ucalgary.ca
Edward Roberts, Professor edward.roberts@ucalgary.ca
Nael Yasri, Research Associate nael.yasri@ucalgary.ca

Department of Chemical and Petroleum Engineering, Schulich School of Engineering, UCalgary

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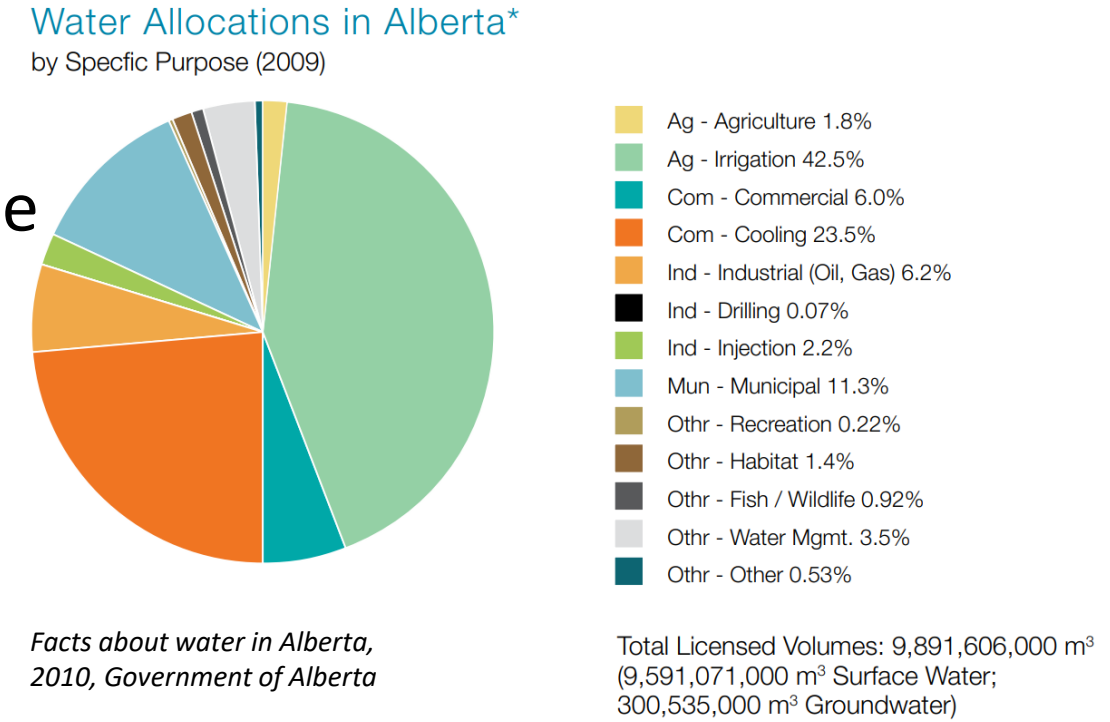
Industrial water usage – Produced water

- ~ 800.000.000 m^3 allocated to industry in Alberta per year
  - From ground and surface water
- Clean (enough) water is becoming scarce
  - Will water become a commodity?



Facts about water in Alberta, 2010, Government of Alberta

Produced water treatment

- No one-stop solution for all contaminants
  - Diversity of contaminants requires diverse treatment

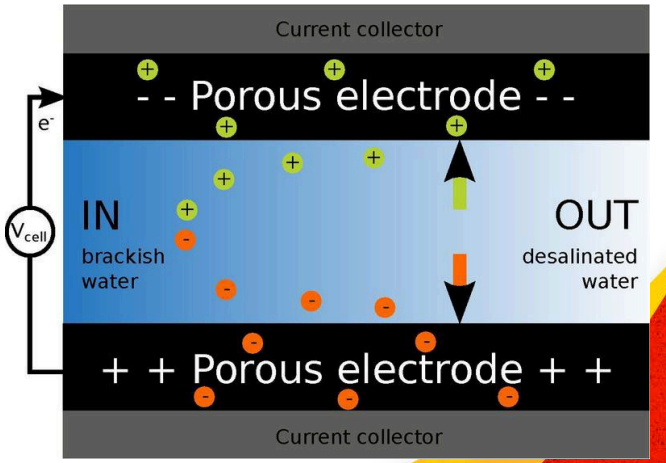
- Process integration and synergies
  - Life cycle analysis for different combinations

1. Electrokinetically driven water treatment

- Specifically useful for brackish water
  - Medium salinity streams
- Electrodialysis
- Capacitive de-ionization

Scope:

- Innovative combinations of techniques
- Development of novel electrode/membrane materials

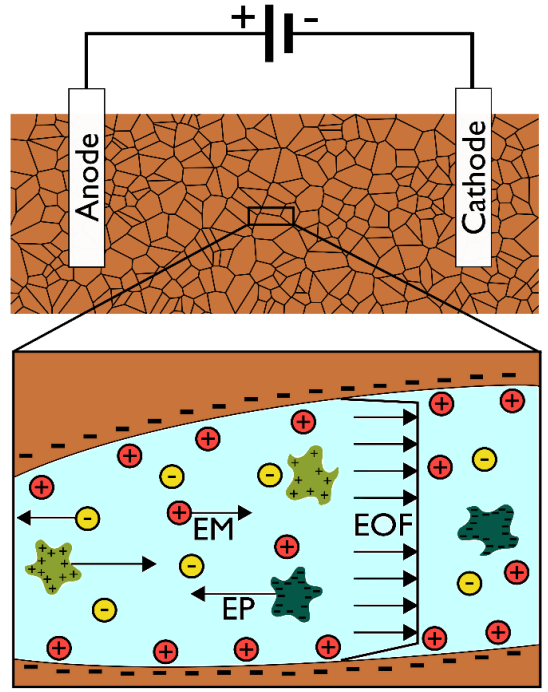


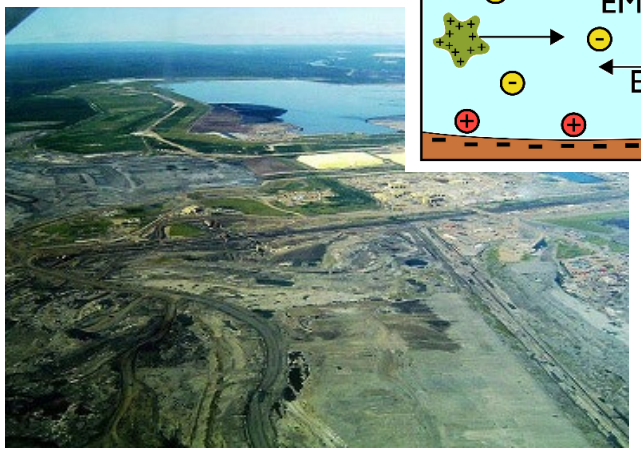
Dewatering of tailings ponds

- Electrokinetic dewatering
  - Not limited by low hydraulic permeability
- Reduce treatment time and increase water recovery

Scope

- Applicability on field scale
- Electrode materials, configuration

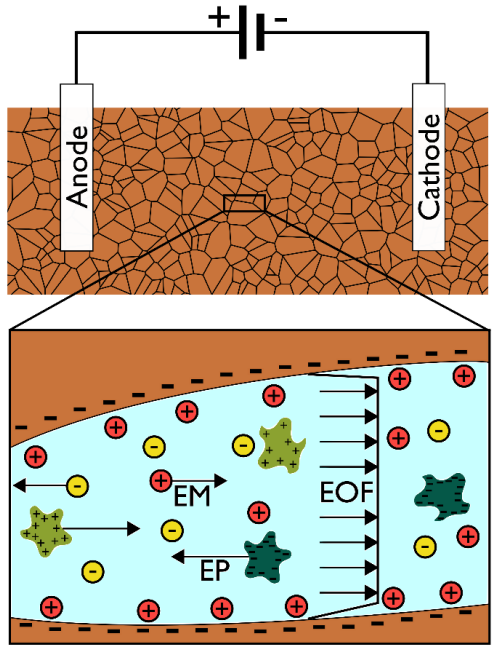




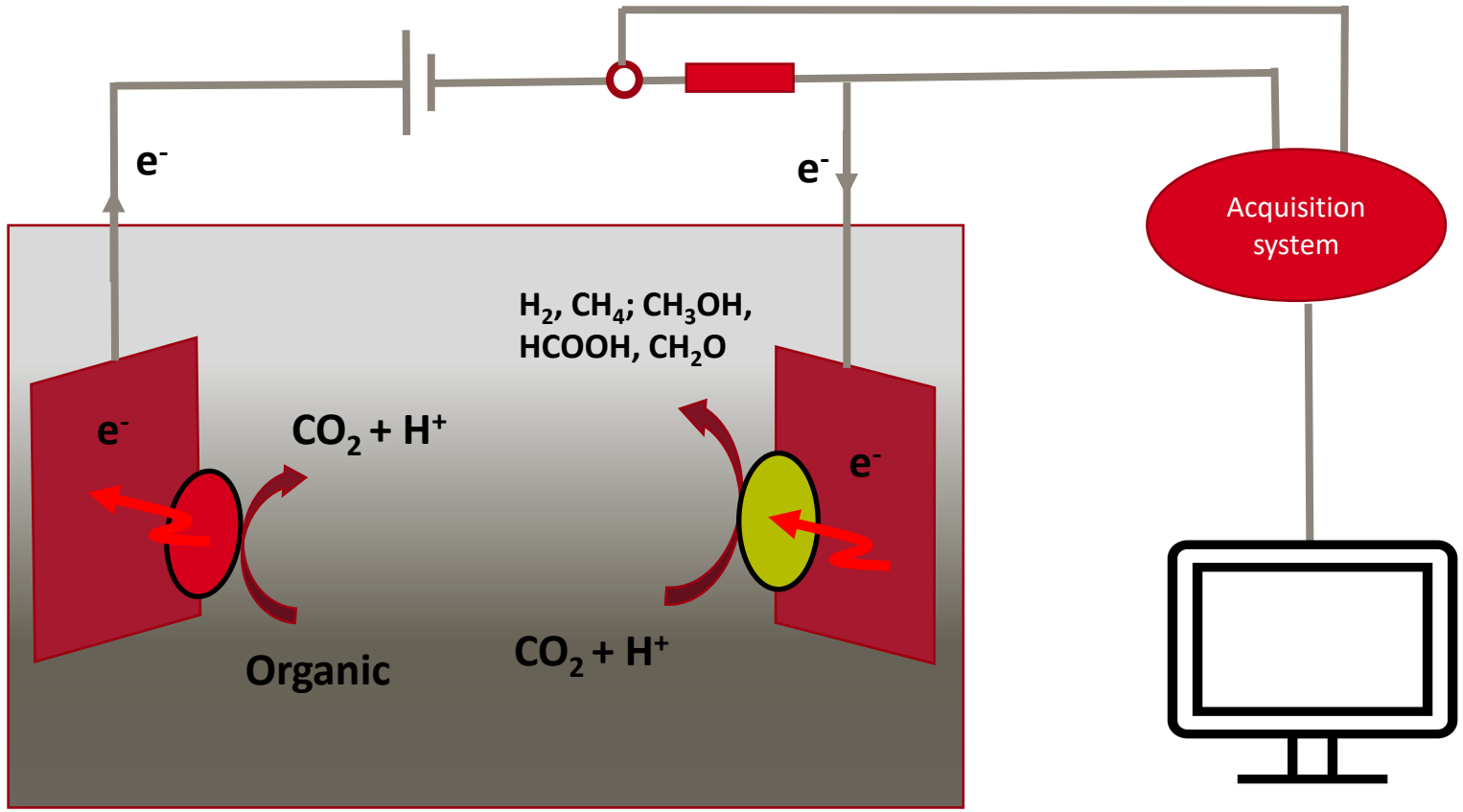
https://energyeducation.ca/encyclopedia/Oil_sands_tailings_ponds

Recovery of valuables from tailings ponds

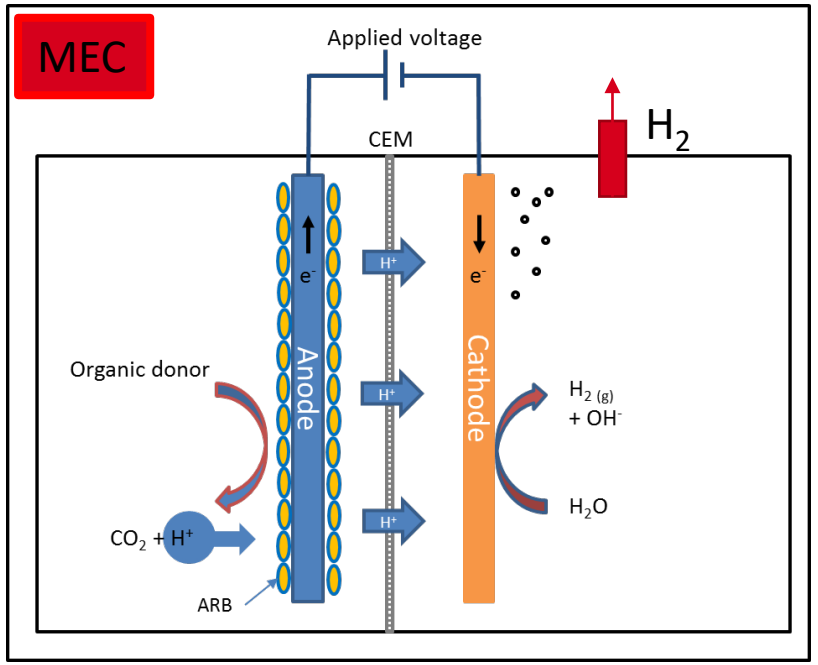
- Electrokinetically (and electrochemically) driven recovery
  - Dissolved or dispersed in aqueous phase
- Reactions for precipitation, recovery at desired location



2. Bio-electrochemical Treatment



Bio-electrochemical principle

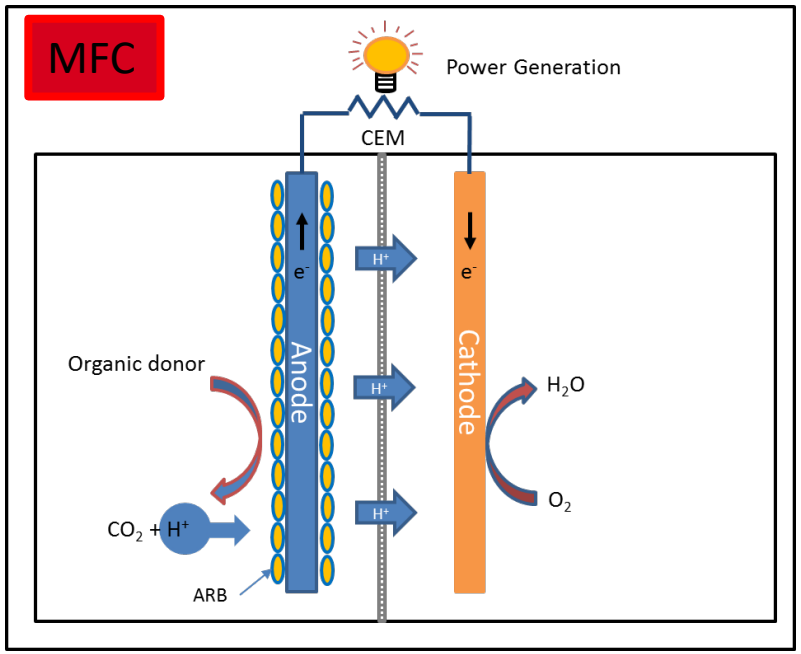


$$2HCO_3^- + 9H^+ + 8e^- \rightarrow CH_3COO^- + 4H_2O$$

$$2H^+ + 2e^- \rightarrow H_2$$

$E_{e,\,cell}$ = (–0.414 V) –(–0.300V)= – 0.114V

Requires energy



$$2HCO_3^- + 9H^+ + 8e^- \rightarrow CH_3COO^- + 4H_2O$$

$$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

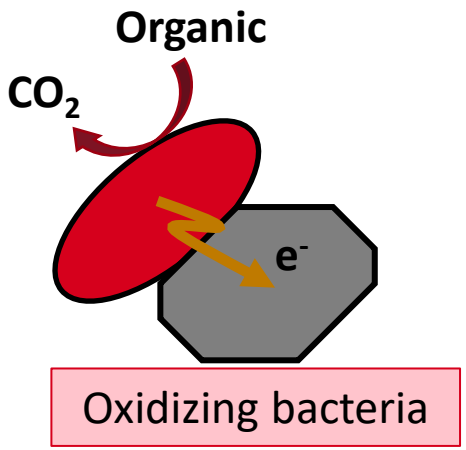
$E_{e,\,cell}$ = (0.805 V) –(–0.300V)= 1.105V

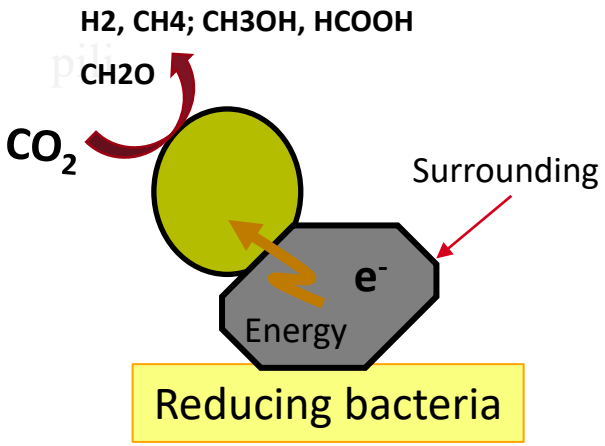
Gives energy

N. Yasri, E. Roberts, Energy Reports, https://doi.org/10.1016/j.egyr.2019.08.007

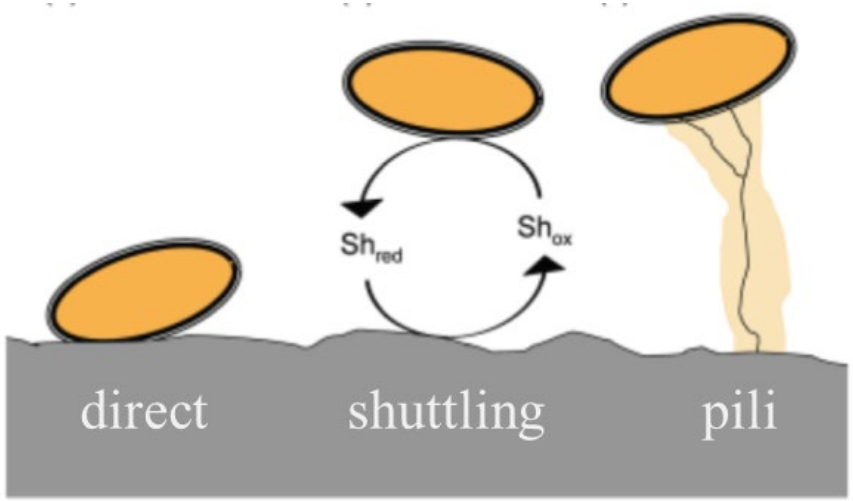
Bio-electrochemical treatment of Mature Fine Tailings

- **Uses Bacteria present in MFT,**
- **Considered biosafety "level 1"**

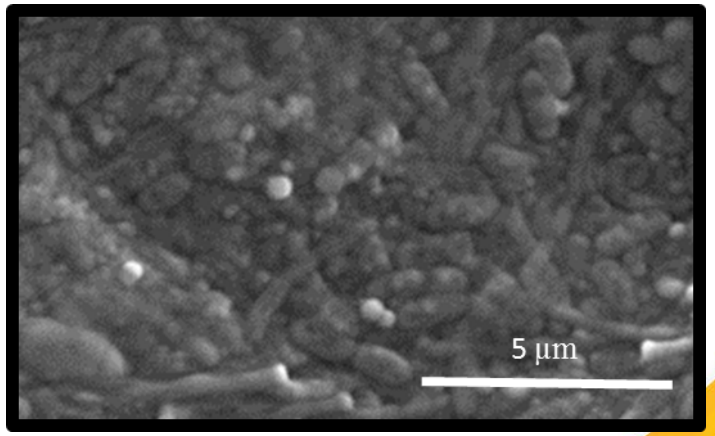




Organics: Asphaltenes, bitumen, soluble organics



Mechanism of Extracellular Electron Transfer (EET)*



SEM image of mature biofilm

Bio-electrochemical treatment of MFT

Three electrode designs

3 days
>70% solids
1 kWh / m^3

Benefits

- Reduced sludge volume
- Water recovery
- Oxidation of toxic organics
- Reduced VOC / GHG emissions
- Low energy consumption
- In-situ or ex-situ technology
- Scalable

Further R&D needed