ENHANCED NATURAL ATTENUATION OF PERCHLORATE IN SOILS USING ELECTROKINETIC INJECTION

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Electrokinetic Processes

- Involves the application of low DC current between electrodes.
- Transport possible by
  - electromigration
  - electroosmosis
- Side reactions
  - electrolysis
  - reactions with electrode

Electrokinetic Remediation

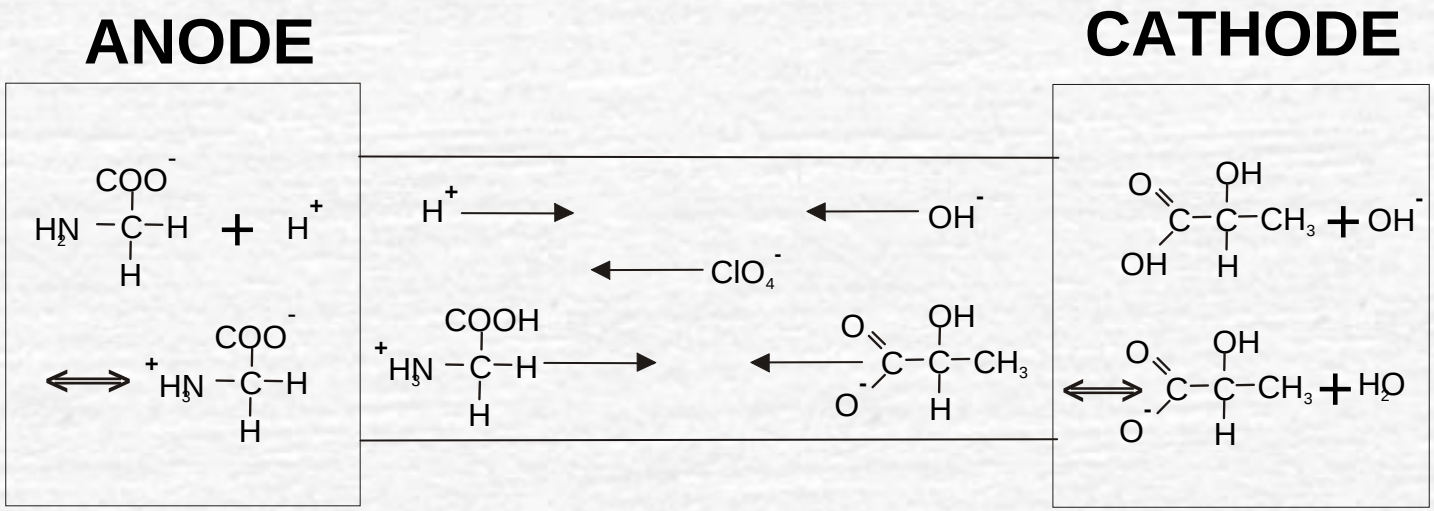
- **Electrokinetic Extraction**: Removal of charged or uncharged species.
  - metals
  - radionuclides
  - organic wastes
- **Electrokinetic Injection**: Addition of species to aid in electrokinetic extraction or other processes.
  - Surfactants
  - Nutrients
  - Electron acceptors
  - Electron donors

Perchlorate ClO_4^-

- Strong oxidant but environmentally stable (abioticaly)
- Biodegradation possible as AEA

$ClO_4^- \longrightarrow ClO_3^- \longrightarrow ClO_2^- \longrightarrow Cl^-$

- Rapid transport through most soils
- Ideal candidate combined EK removal and injection of organic substrates to promote NA


ANODE
CATHODE
COO-
H2N – C – H
H
+
H+
COO-
+H3N – C – H
H
H+
OH-
ClO4-
COOH
+H3N – C – H
H
O
OH
C – C – CH3
O-
H
O
OH
C – C – CH3 + OH-
OH
H
O
OH
C – C – CH3 + H2O
O-
H

Objectives

- To determine the potential for enhanced attenuation of PC using electrokinetic removal and injection .
  - Evaluate potential for physical removal of PC from saturated media
  - Evaluate potential for accelerated bioremediation of PC by injecting organic substrates using electrokinetics.

Experiments Conducted

- Microcosm Study
- Electrokinetic Injection and Removal
  - Clay (2)
  - Sand (2)
  - Soil (2)

Microcosm Study

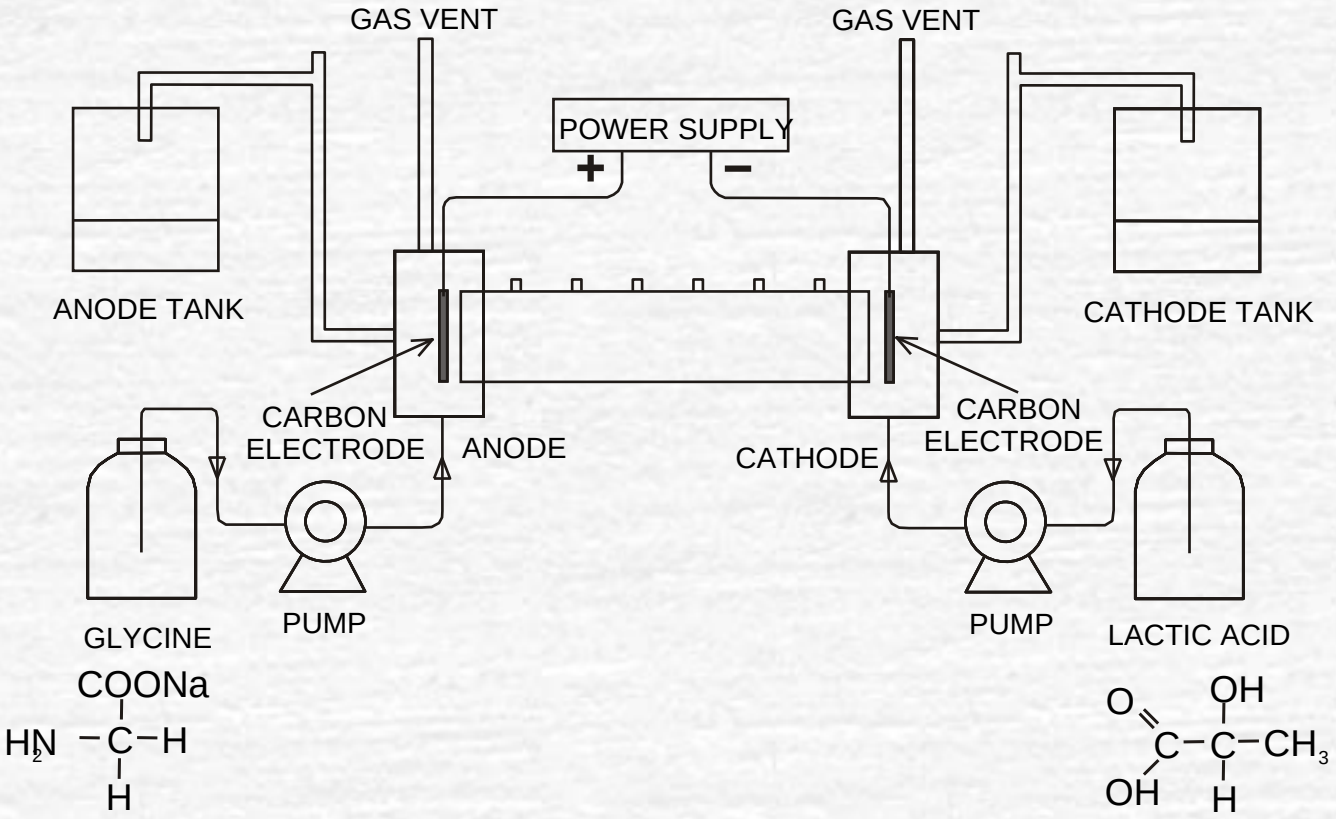
Table 1. Experimental conditions for PC degradation studies.

Treatment	Soil	Water	PC	Lactic	Glycine
Autoclaved	50g	50ml (DI)	10mg/kg	-	-
Control	50g	50ml (DI)	10mg/kg	-	-
Uncontaminated	50g	50ml (DI)		-	-
Lactic	50g	50ml (DI)	10mg/kg	3mM	-
Glycine	50g	50ml (DI)	10mg/kg		3 mM
Lactic/Glycine	50g	50ml (DI)	10mg/kg	3 mM	3 mM

Microcosm Results

Treatment	Pseudo-first Order Degradation Rate(day^{-1})
Control	0.185
Lactate	0.748
Glycine	1.62

Schematic of electrokinetic set-up

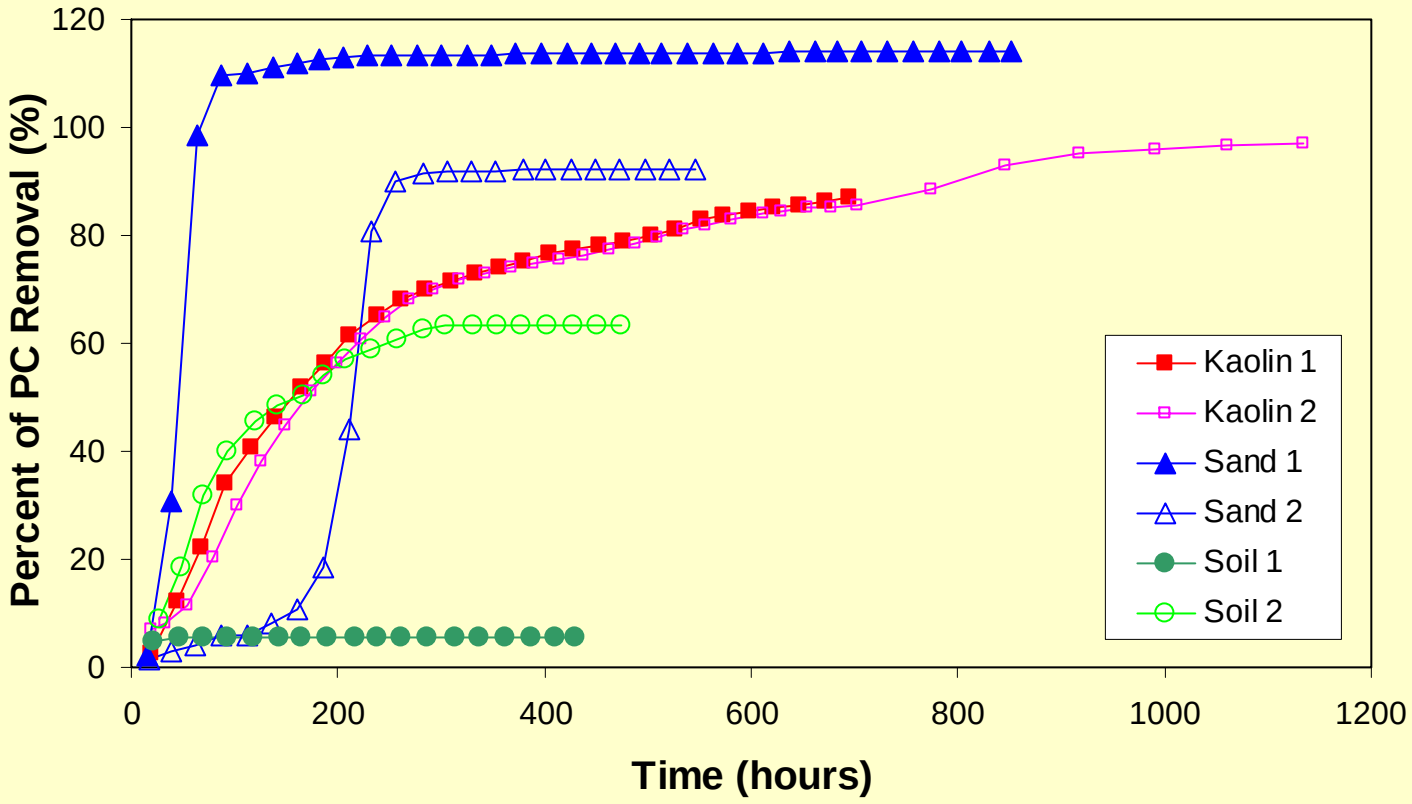


Work Plan (EK Studies)

Table 2. Details of EK column studies

	Kaolin 1	Kaolin 2	Sand 1	Sand 2	Soil 1	Soil 2
Material	100 % kaolin	100 % kaolin	No.3 BlastSand	Grade 4 BlastSand	Sub-surface Lean Clay Soil	Sub-surface Lean Clay Soil
Bulk density (g/cm^3)	1.0	1.0	1.64	1.52	1.2	1.2
Duration (hr)	694	1134	852	547	429	474
Current (mA)	17	24	3	7	5	5
Lactic conc. (mM)	20	20	5	5	5	5
Glycine conc. (mM)	20	20	5	5	5	5

Physical PC Removal using Electrokinetics

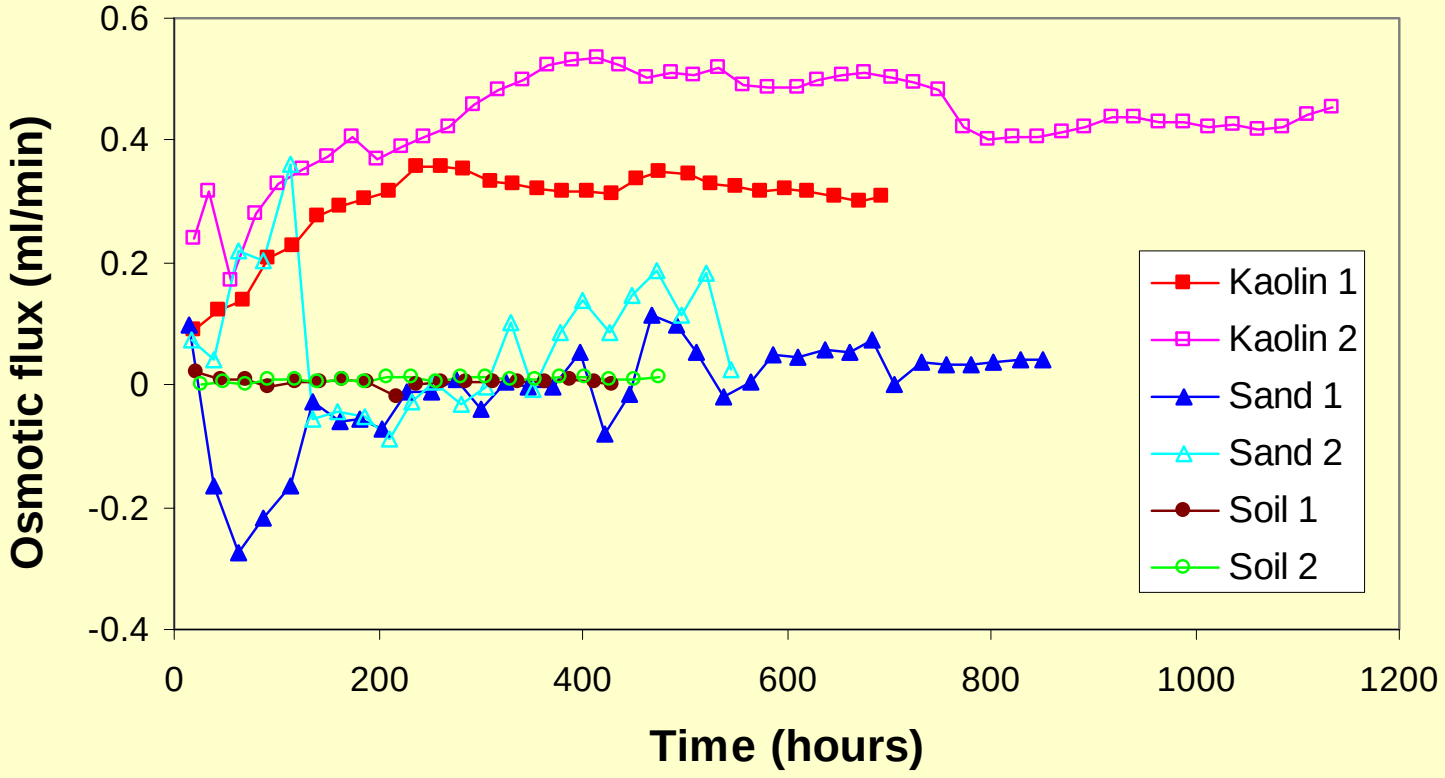


PC Removal by Electrokinetics

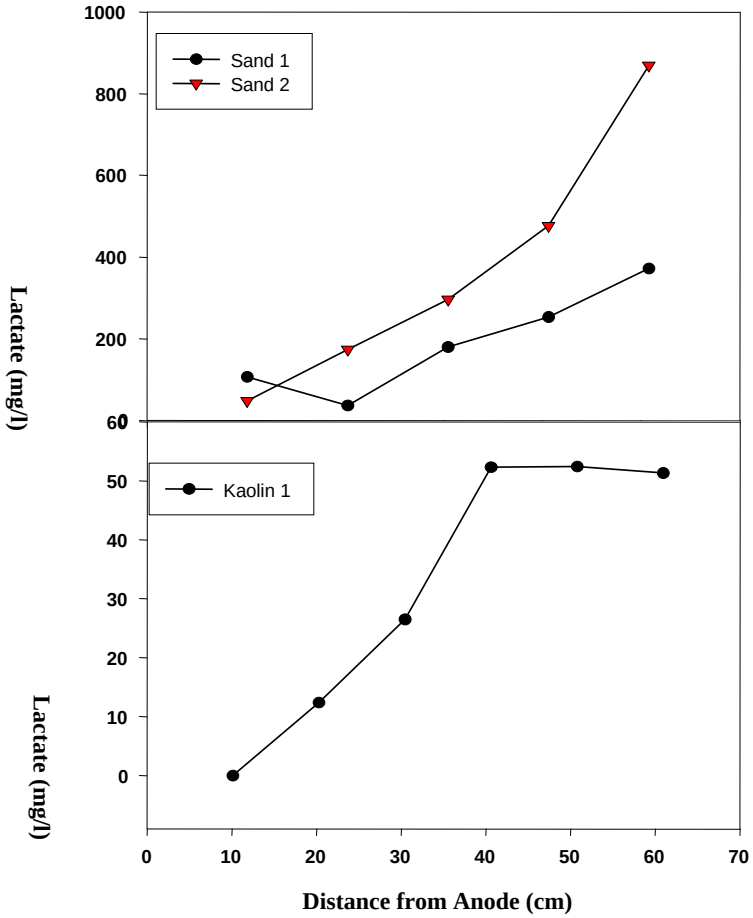
Table 3. PC removal from sand and kaolin by electrokinetics.

	Duration (hours)	% Removal (Anode)	% Removal (Cathode)	% Removal (Total)
Kaolin 1	694	86.69	0.23	86.92
Kaolin 2	1134	96.71	0.19	96.90
Sand 1	852	112.48	1.64	114.12
Sand 2	547	91.28	1.06	92.34
Soil 1	429	0.11	5.49	6.68
Soil 2	474	63.39	0.00	63.39

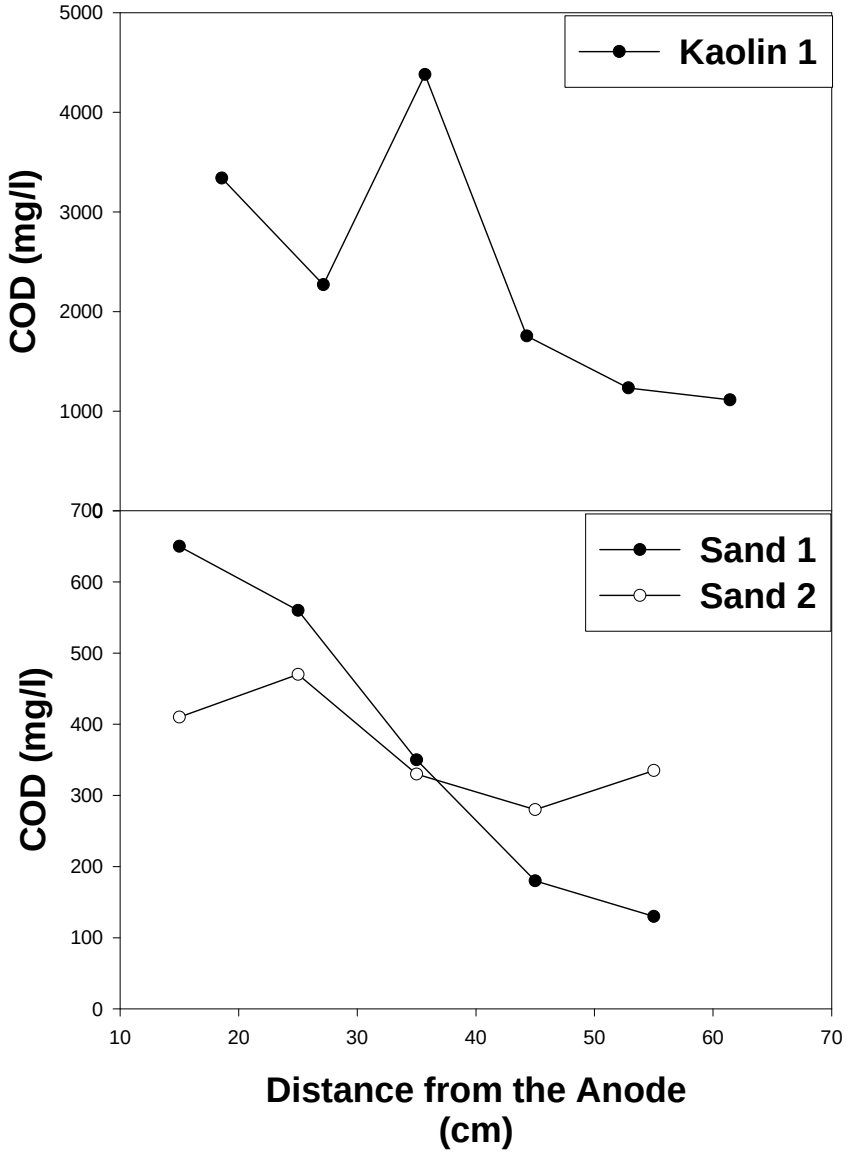
Osmotic flux at Cathode



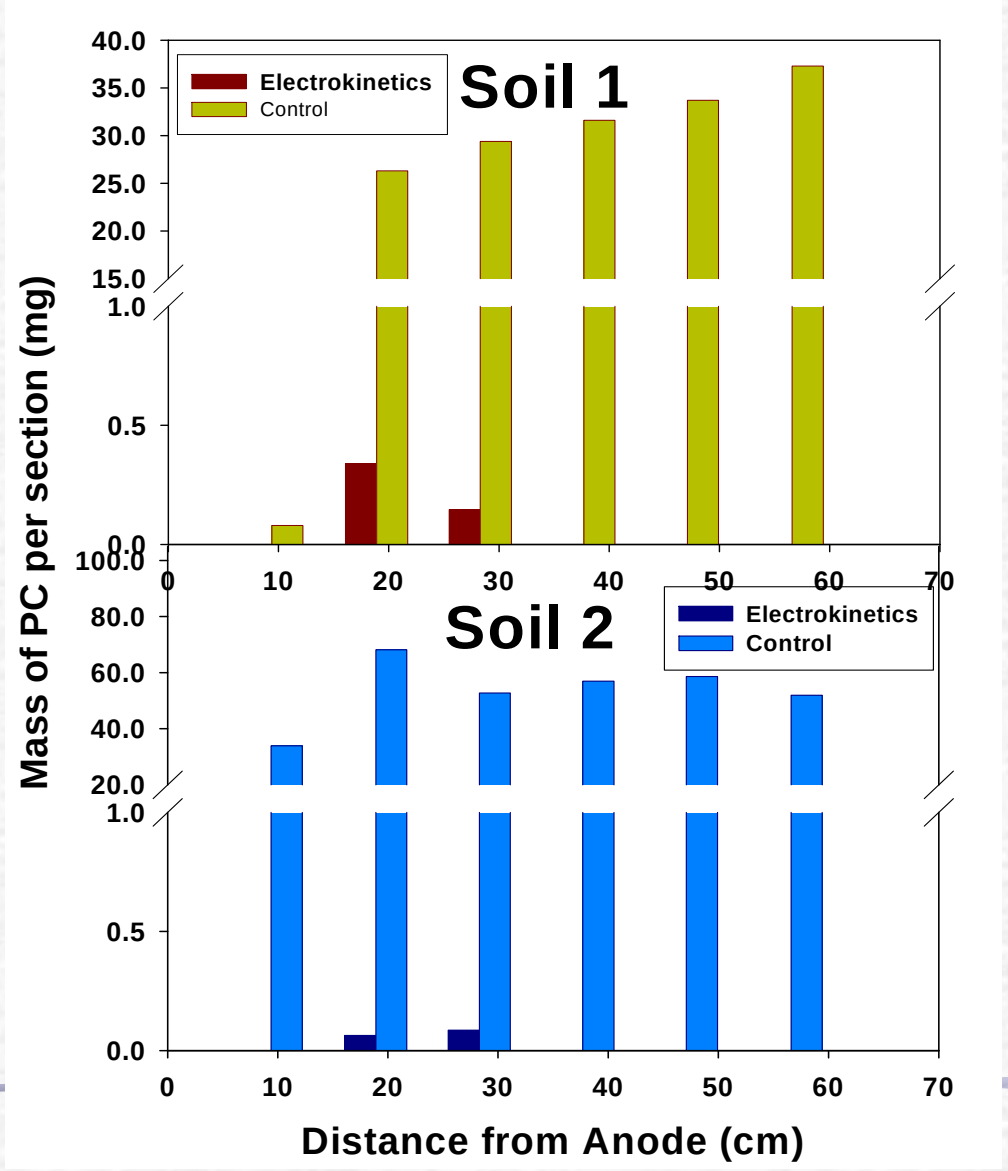
Transport of Lactate by Electrokinetic Injection



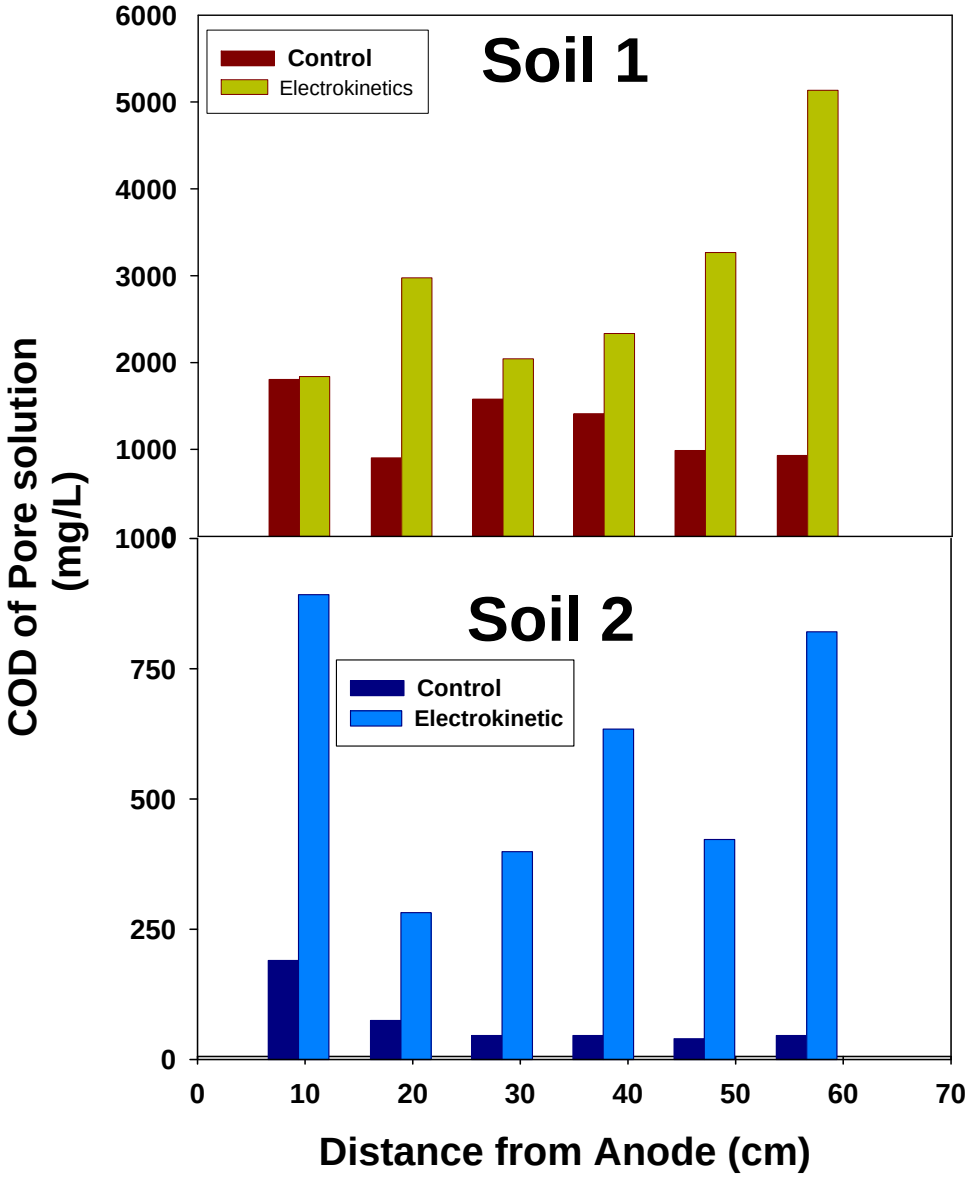
Chemical Oxygen Demand of Porewater at the Termination of the Experiments



Mass of PC in Soil Column at the End of Experiments



Chemical Oxygen Demand of Pore Water at Termination of the Experiment



Conclusions

- Electrokinetics promising technology to aid in the removal of PC from contaminated soil.
- Electrokinetics promising technology to introduce organic amendments to enhance natural attenuation
- Combining these technologies will provide even greater benefits