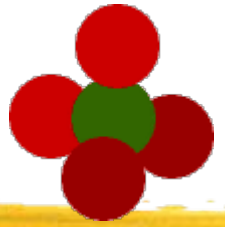
Attachment 6

Perchlorate in Groundwater:



Established Treatment Processes / Remedial Action Alternatives

Johnnie Shockley & Charles G. Coyle P.E.

U.S. Army Corps of Engineers

Hazardous, Toxic, and Radioactive Waste Center of Expertise

Overview

- Properties of Perchlorate
- Established Treatment Processes
  - ion exchange
  - reverse osmosis
  - biological treatment
- Remedial Action Alternatives
  - Ex-Situ Treatment
  - In-Situ Treatment
    - **(electron donor injection)**

Perchlorate properties

- anion (-1)
- very high water solubility
- highly mobile, like nitrate

Established Treatment Processes

- Biological treatment
- Ion exchange
- Reverse osmosis / Nanofiltration

Remedial Action Alternatives

- Ex-Situ (pump & treat)
  - ion exchange
  - reverse osmosis
  - biological treatment
- In Situ Treatment Proposals
  - biological treatment

Treatment Processes
Ion Exchange

- Calgon ISEP+ System
- O&M costs estimated at about 2 times the cost of biological treatment
  - **treatment/disposal of brine required**
    - **250 deg C + catalyst (energy intensive)**

Treatment Processes
Reverse Osmosis

- Removal efficiency > 80%
  - approx. 30 ppb to < 4 ppb
- O&M costs
  - **treatment/disposal of reject stream required**

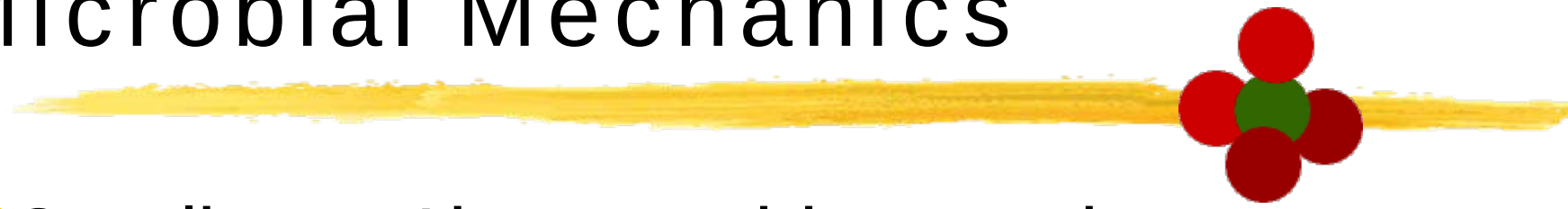
Treatment Processes
Biological

- Removal efficiency > 80%
  - approx. 150 ppb to < 4 ppb
- Scale 3200 gpm system @ Aerojet facility planning to expand to 8000 gpm
- O&M costs approx. $0.21 per 1000 gal*
  - **complete destruction!** (no reject or brine)
  - *includes ethanol, nutrients & utilities

Electron Donor Injection for In-Situ Bioremediation of TCE

- Has been used at several sites to treat chlorinated solvents and is also applicable to nitrates & perchlorate
- Defense Depot Hill Utah, Ogden Site
- Former Atlas Site 10 near York, NE
- Idaho National Engineering & Environmental Laboratory

Microbial Mechanics



- Gasoline + Air --- > drives engine
- Gasoline (electron donor)
- Air (electron acceptor)

Electron Acceptors

- Oxygen
- Nitrate
- Iron III
- Sulfate
- Carbon Dioxide

Electron Acceptors

- Oxygen
- Nitrate / Perchlorate
- Iron III
- Sulfate / Chlorinated Solvents
- Carbon Dioxide

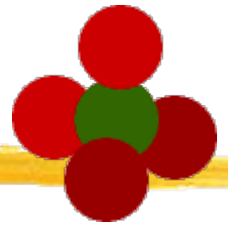
Electron Donors

- Ethanol (ex-situ, Aerojet bioreactor)
- Hydrogen Release Compound
- sodium lactate solution
- vegetable oil

Microbial Mechanics

Electron Acceptor		Electron Donor	
oxygen		lactate	
nitrate	+	ethanol	→ drives microbe
perchlorate		veg oil	

Electron Donor Injection



- Has been used at several sites to treat chlorinated solvents and at some sites to treat nitrates
- Principles are the same for perchlorate
- Perchlorate degrading microbes appear to be ubiquitous
- Risk of mobilizing some metals (e.g., arsenic)

Former Atlas 10 Site
HRC Field Demonstration

- TCE contaminated groundwater
- relatively high-permeability aquifer
- water table at about 60 feet bgs
- HRC injected from about 75 to 60 ft bgs

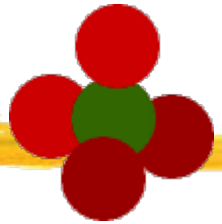

CAUTION CAUTION CAUTION

Defense Depot Hill Utah Vegetable Oil Barrier

- TCE contaminated groundwater
- relatively high-permeability aquifer
- water table at about 20 feet bgs
- source removal (dig & haul)
- vegetable oil for treatment of source area residual


DAEWOO

Conclusions



- Reverse osmosis, ion exchange & bio-reactors capable of approx. 80% (or greater) removal of perchlorate
- For large scale ex-situ treatment, bio-reactors appear to be more cost-effective than ion exchange or reverse osmosis
- In-situ bio-treatment appears to be a promising alternative if site geology permits