

A photograph of the Space Shuttle Columbia during its ascent, showing the orbiter, external tank, and solid rocket boosters. The shuttle is angled upwards against a clear blue sky, with a large plume of white smoke and fire at the base.

# **In Situ Bioremediation of Perchlorate in Groundwater**

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Director, ESTCP  
Technical Director, SERDP**

**Federal Remediation Technologies Roundtable  
General Meeting  
May 30, 2001**

## SERDP

- **Research on In Situ Remediation (FY00-FY02)**
- **Ecotoxicity (FY99-FY01)**

## ESTCP

- **In Situ Remediation Demonstrations (FY02 New Starts)**

## University of Southern Illinois (Dr John Coates)

- Isolation and identification of  $\text{ClO}_4$ -degrading bacteria
- Development of rapid identification test kit for  $\text{ClO}_4$ -reducers

## Envirogen (Dr Paul Hatzinger) & USN - Indian Head (Carey Yates)

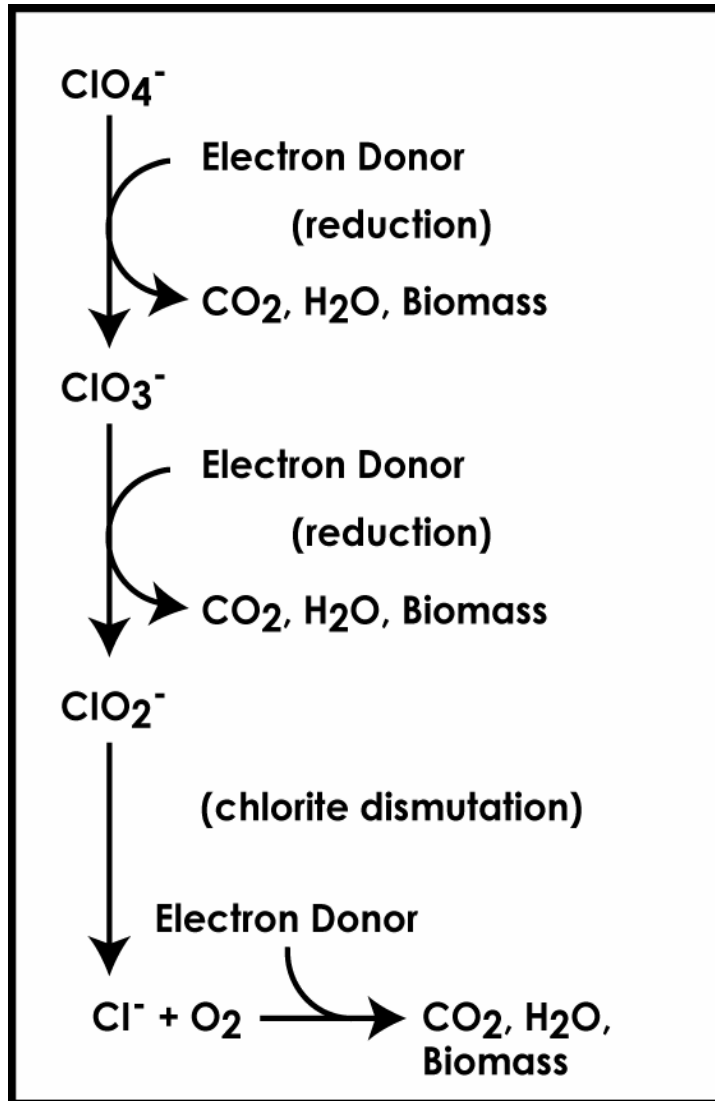
- Define key environmental factors affecting  $\text{ClO}_4$  biodegradation
- Column studies to determine kinetic parameters for  $\text{ClO}_4$  reduction
- Update current flow/reactive transport models to include  $\text{ClO}_4$

## GeoSyntec (Evan Cox) & U. of Toronto (Dr Elizabeth Edwards)

- Microcosm studies to assess ubiquity of  $\text{ClO}_4$ -reducers & assess joint biodegradation of  $\text{ClO}_4$  & solvents
- Field demonstration of in situ bioremediation

## DoD Liaison - Bryan Harre (NFESC)

# Accomplishments



- **Perchlorate-reducers appear to be ubiquitous in subsurface environments**
- **Use perchlorate as an electron acceptor**
- **A wide variety of carbon substrates can serve as electron donors**
- **Reaction occurs under anaerobic-reducing conditions**

## Collected Aquifer Samples from Multiple Sites



### Envirogen

**Jet Propulsion Lab, CA**

**Indian Head NSWC, MD (2 Sites)**

**Rocky Mountain Commercial Site**

**Oyster Virginia (*Pristine Site*)**

**Longhorn AAP, TX (3 Sites)**

### GeoSyntec

**Aerojet Superfund Site ITRCS, CA**

**Edwards AFB, CA**

**U.S. Navy San Nicolas Island, CA**

**Allegany Ballistics Laboratory, WV**

**American Pacific Corporation, NV**

**Boeing Alpha/Sigma Complex, CA**

# Accomplishments



## Preliminary Conclusions from Microcosm Studies

- Choice of Electron Donor Site Specific
- Low pH (< 5) Inhibitory to Perchlorate Degradation
- Oxygen Inhibitory to Perchlorate Degradation
- Nitrate and Nitrite Degraded before Perchlorate
- Joint Reduction of Sulfate Problematic at Some Sites



Substrate	Jet Propulsion Lab	Rocky Mountain	Indian Head (Bldg 1170)	Indian Head (Hogout)
Hydrogen	Blue	Grey	Red	Grey
Propane	Blue	Grey	NA	Grey
Acetate	Red	Blue	Red	Grey
Lactate	Red	Red	NA	Grey
Benzoate	Grey	Grey	NA	Grey
Methanol	Blue	Grey	NA	Grey
Ethanol	Red	Grey	Grey	Grey
Molasses	Red	Red	Blue	Grey
YE/Ethanol	Red	Red	NA	Grey
Sucrose	Blue	Red	NA	Grey
FBR2-Culture	Red	Red	Blue	Grey

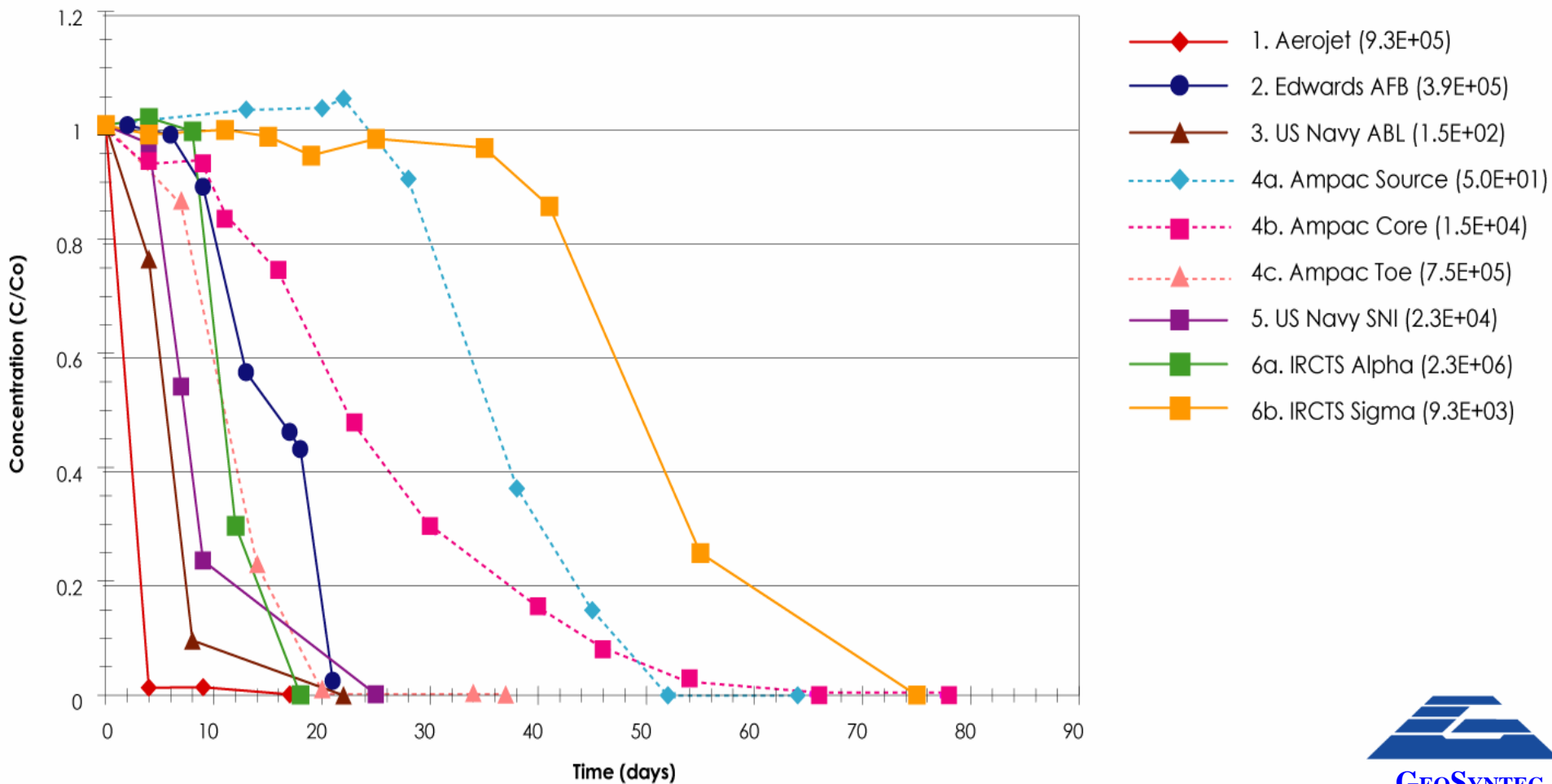
Rapid Biodegradation ( $\leq 14$  Days)  
 Slow Biodegradation ( $\geq 14$  Days)  
 No Biodegradation



# Accomplishments



## ClO<sub>4</sub> Biodegradation in Acetate Treatments - All Sites MPNs for Perchlorate-Degraders (cells/mL) in Parentheses



# Accomplishments



## Summary of Electron Acceptor Use

Site #	Site Name	Nitrate Concentration (mg/L)	Perchlorate Concentration (mg/L)	Sulfate Concentration (mg/L)	Order of Acceptor Utilization
1	Aerojet	5.0	110	15	<b>N = P &gt; S</b>
2	Edwards AFB	<1.2	102	179	<b>P &gt; S</b>
3	US Navy - ABL	3.8	9.8	54	<b>N = P &gt; S</b>
4a	AMPAC Source	7.6	92	1620	<b>N &gt; P &gt; S</b>
4b	AMPAC Core	59	329	633	<b>N = P &gt; S</b>
4c	AMPAC Toe	30	666	473	<b>N &gt; P &gt; S</b>
5	US Navy - SNI	4.0	100	85	<b>N &gt; P = S</b>
6a	IRCTS Alpha	1.0	102	19	<b>N &gt; P = S</b>
6b	IRCTS Sigma	4.4	42	16	<b>N &gt; P &lt; S</b>



# Planned Activities



- **Development of a molecular probe for rapid detection of perchlorate-reducers**
- **Field-scale experiment of in situ bioremediation starting Mar 01**
  - **Aerojet Superfund Site, California;**
- **Expected completion - December 2001**

# Conclusions Thus Far



- **Perchlorate-degrading bacteria appear to be ubiquitous**
- **In situ bioremediation appears to be robust technology for**
  - **Groundwater source or plume core destruction**
  - **Migration control**
- **Key challenge will be electron donor delivery**
- **Acetate appears to be best substrate**
- **Potential for slow-release donors - edible oils**
- **Potential competitive effects due to nitrate or sulfate**

## Texas Tech University (CU-1141 & CU 1223)

- Aquatic Toxicology - evaluate potential perchlorate-induced effects in amphibians and fish.
- Terrestrial Toxicology
  - Soil Ecotoxicology: Evaluate potential for perchlorate bioaccumulation in earthworms.
  - Rodents: Determine effects of perchlorate on thyroid hormone activity, development and reproduction in wild rodents.
  - Medium Sized Mammals: Determine effects of perchlorate on thyroid hormone activity in higher trophic level organisms associated with a terrestrial/aquatic interface.
- Molecular Toxicology: Identify/characterize molecular markers that are indicators of perchlorate exposure in amphibians, reptiles, and mammals.
- Environmental Modeling: Develop a terrestrial food chain and an aquatic food chain model for perchlorate.

## Southern Nevada Water Authority (CU 1222)

- Lab and field studies to determine the toxicological impact of ammonium perchlorate on fish. Field studies to be done on carp in Lake Mead.

### Texas Tech University (CU-1235)

- Avian Exposure Studies: Assess effects of perchlorate exposure to aquatic and terrestrial avian species. Assessments monitored via blood residues, thyroid hormone profiles, nesting success, survival, growth of fledglings, and residues in eggs.
- Food Item Transfer of Perchlorate into Rodents: Evaluate potential food web-related exposure pathways.
- Aquatic Toxicology:
  - Compare uptake of perchlorate in different fish species and different trophic levels
  - Examine perchlorate elimination rates in fish.
  - Using mosquitofish, examine effects of perchlorate exposure on gonadal histopathology, fecundity, egg volume and fry size, and fry growth in the laboratory.
  - Examine the effects perchlorate exposure to UV radiation sensitivity in frogs.
- Assess sensitivity of perchlorate toxicity to windows of development in amphibians and possible mitigating effects of naturally occurring iodine.
- Aquatic Plant Modeling: Adapt and integrate existing plant models into an aquatic food chain model and an avian PBPK model .

# SERDP Efforts - Ecotoxicology FY01 New Start Projects



## Oklahoma State University (CU-1236)

- Examine the Effects of Ammonium Perchlorate on Reproduction and Development of Amphibians:
  - Investigate effects of continuous long-term exposure.
  - Examine possible mitigating effects of naturally occurring iodine on perchlorate toxicity.
  - Determine the effect of perchlorate derived from food sources on amphibian development.
  - Investigate changes in pigmentation and sensitivity to UV radiation due to perchlorate exposure.
  - Observe the effects of perchlorate on reproductive capacity of female *Xenopus*.

**“In Situ abiotic and biotic technologies are sought that specifically address that cleanup of groundwater contaminated with perchlorate. Technologies for the cost effective treatment of either aqueous phase plumes or the higher strength source zones are of interest.”**

- **Anticipate selecting multiple technology demonstrations for funding.**
- **Contracts will be awarded March 02.**
- **Interested in conducting demos in partnership with Service Agencies**