Biological Treatment of Groundwater Containing Perchlorate Using Fluidized Bed Reactors

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Presentation Outline

1. Envirogen/USFilter Partnership
2. Perchlorate Biological Degradation
3. Selection of Reactor Type
4. Fluidized Bed Reactor
5. Case Histories
   - Pilot
   - Full-Scale
6. Summary

Envirogen-USFilter Relationship

- Joint Marketing for Perchlorate and MTBE applications
- Envirogen focus - microbiology and biocatalysts
- USFilter focus - systems and hardware
- Strong synergy between the two organizations

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Bacterial Metabolism

- **Requirements:**
  - Energy Source (organic or inorganic)
  - Electron Acceptor (O_2, NO_3, SO_4, CO_2)
  - Carbon Source (organic or CO_2)
  - Macronutrients (N,P,S)
  - Mineral Ions (Ca, K, Mg, Fe, Cu, Zn, Co, et al.)
  - Vitamins and/or Amino Acids

Biological Perchlorate Reduction

Terminal Electron Acceptor:

$$ClO_4^- \longrightarrow ClO_3^- \longrightarrow ClO_2^- \longrightarrow O_2 + Cl^-$$

(perchlorate) (chlorate) (chlorite)

$$O_2 \longrightarrow H_2O$$

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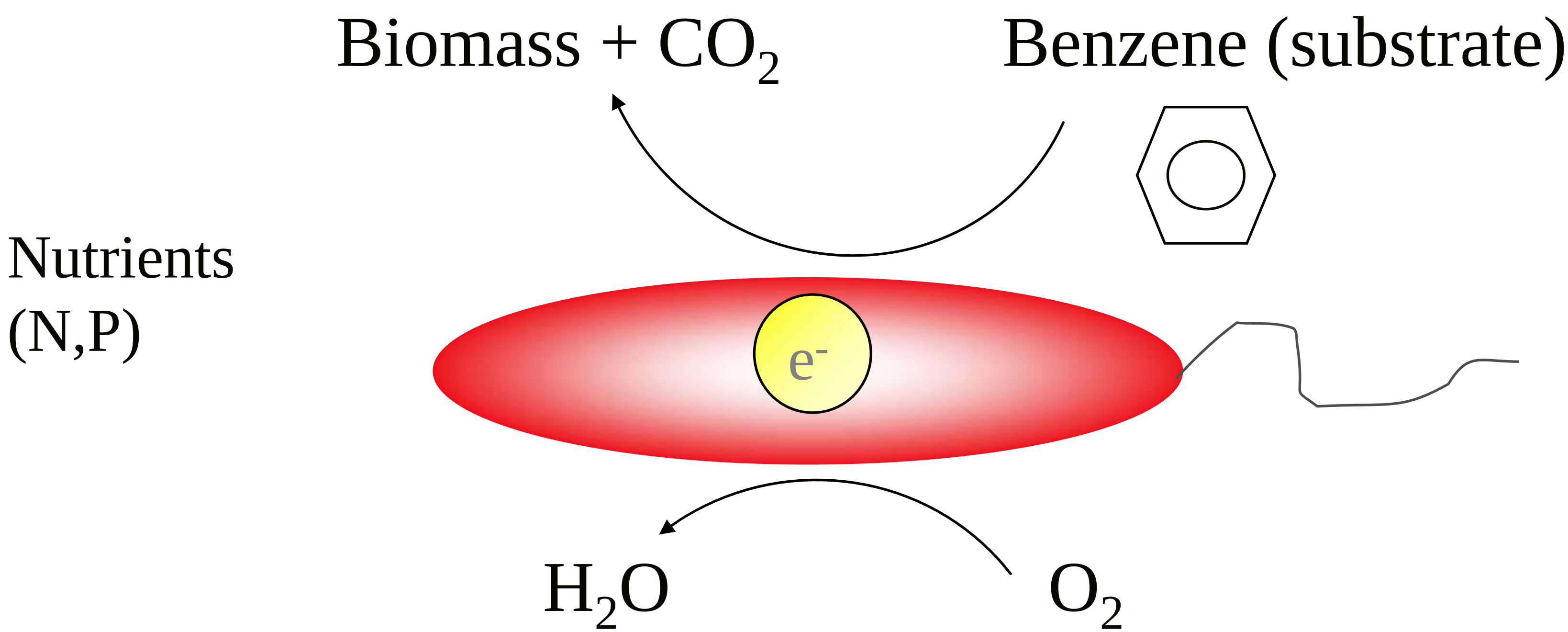
Organic Pollutants



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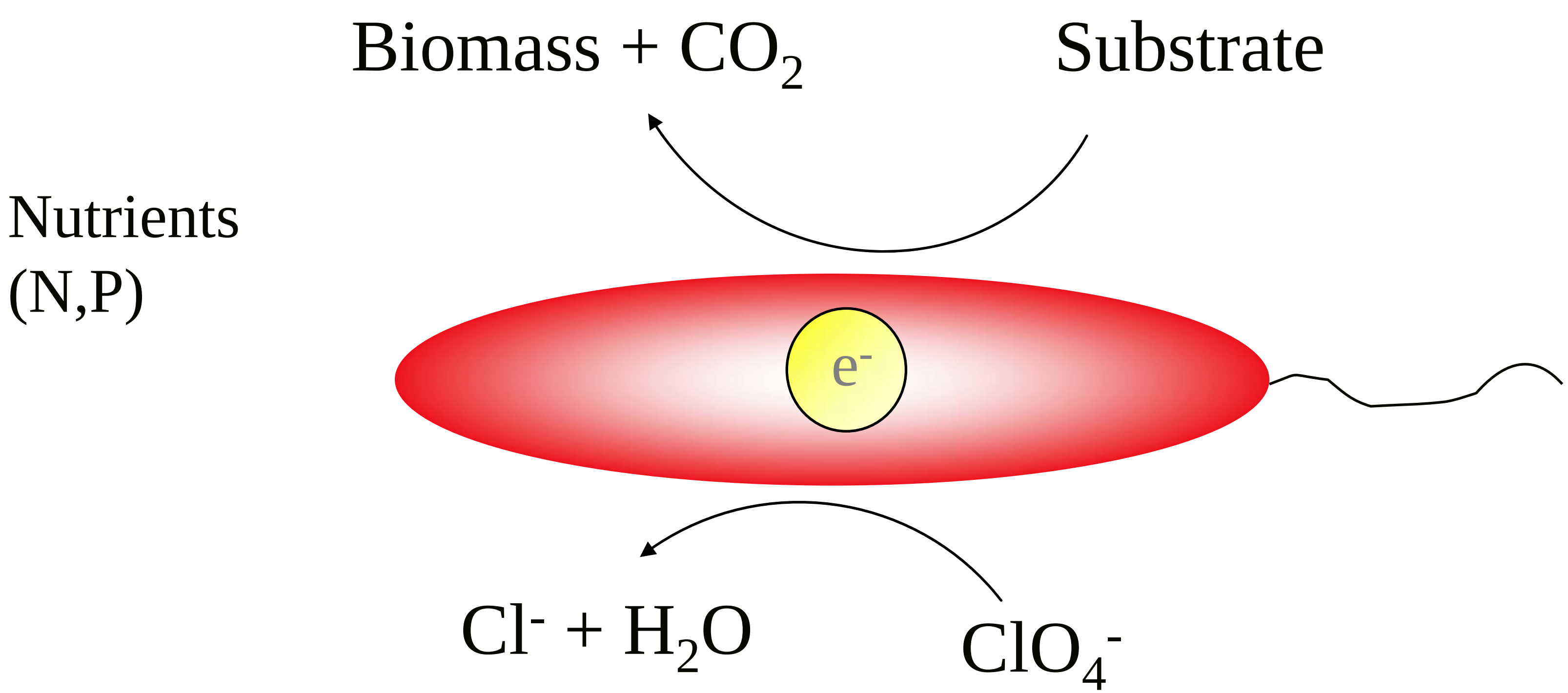
Perchlorate



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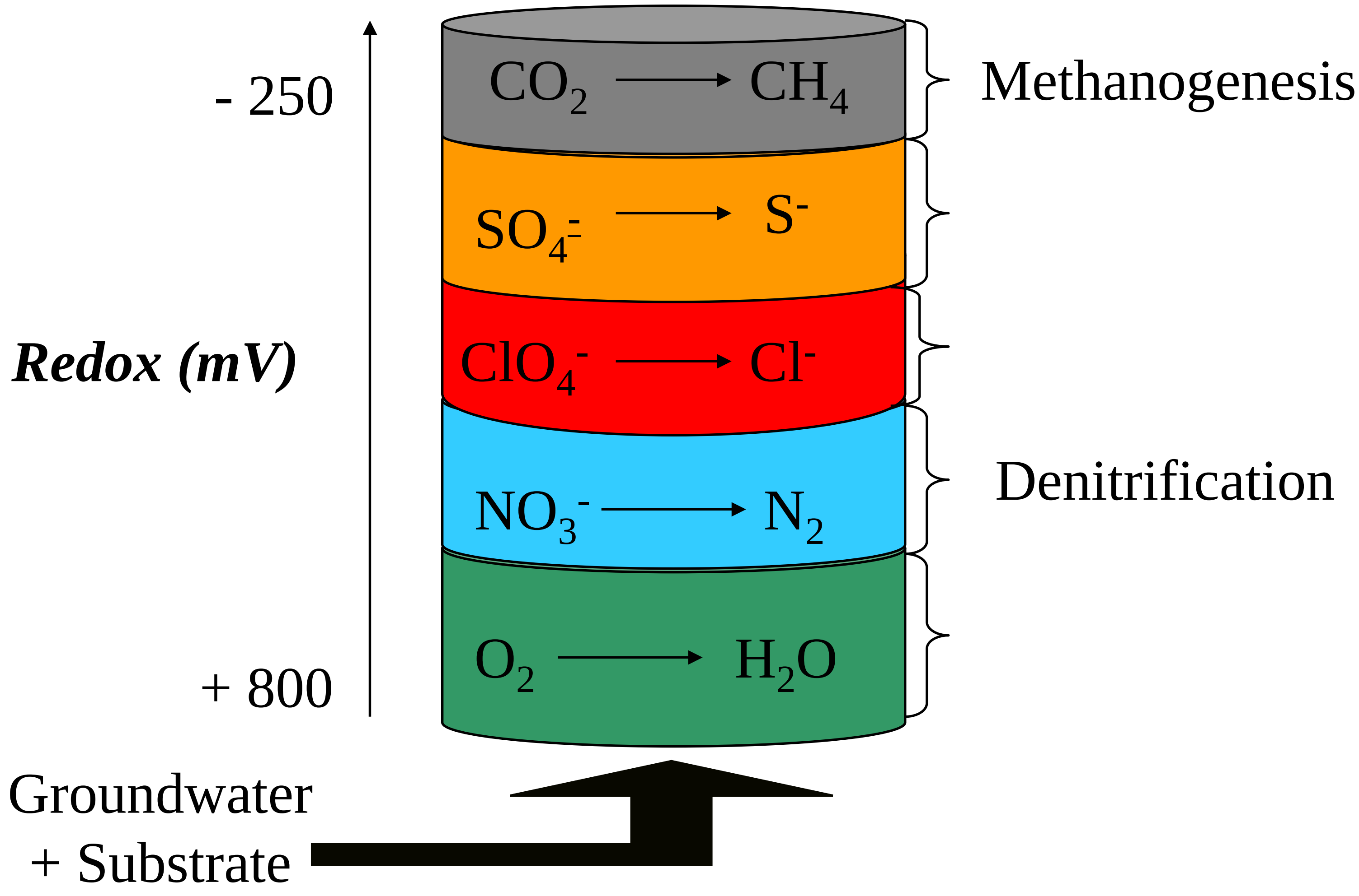
Utilization of Electron Acceptors



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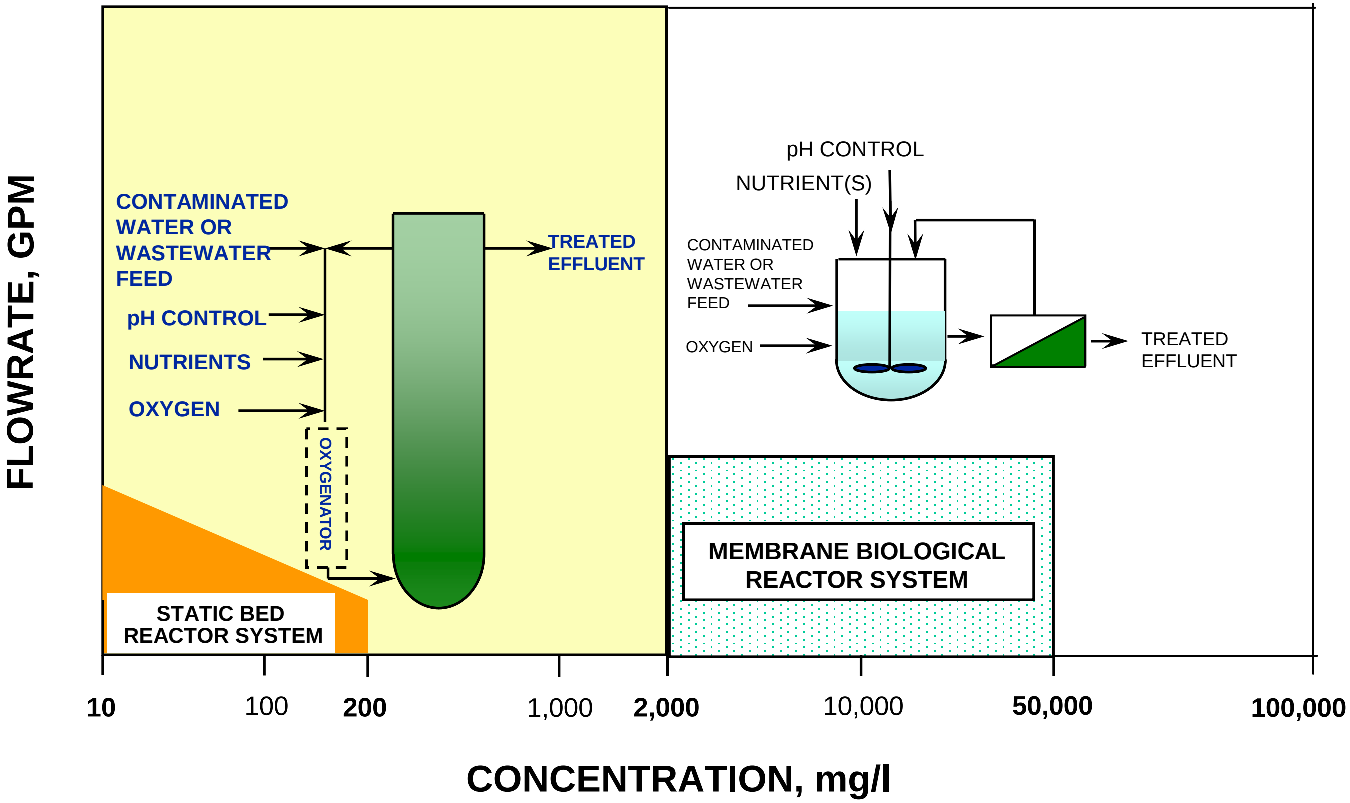
Bioreactor System Options for Treatment of Organic Chemicals



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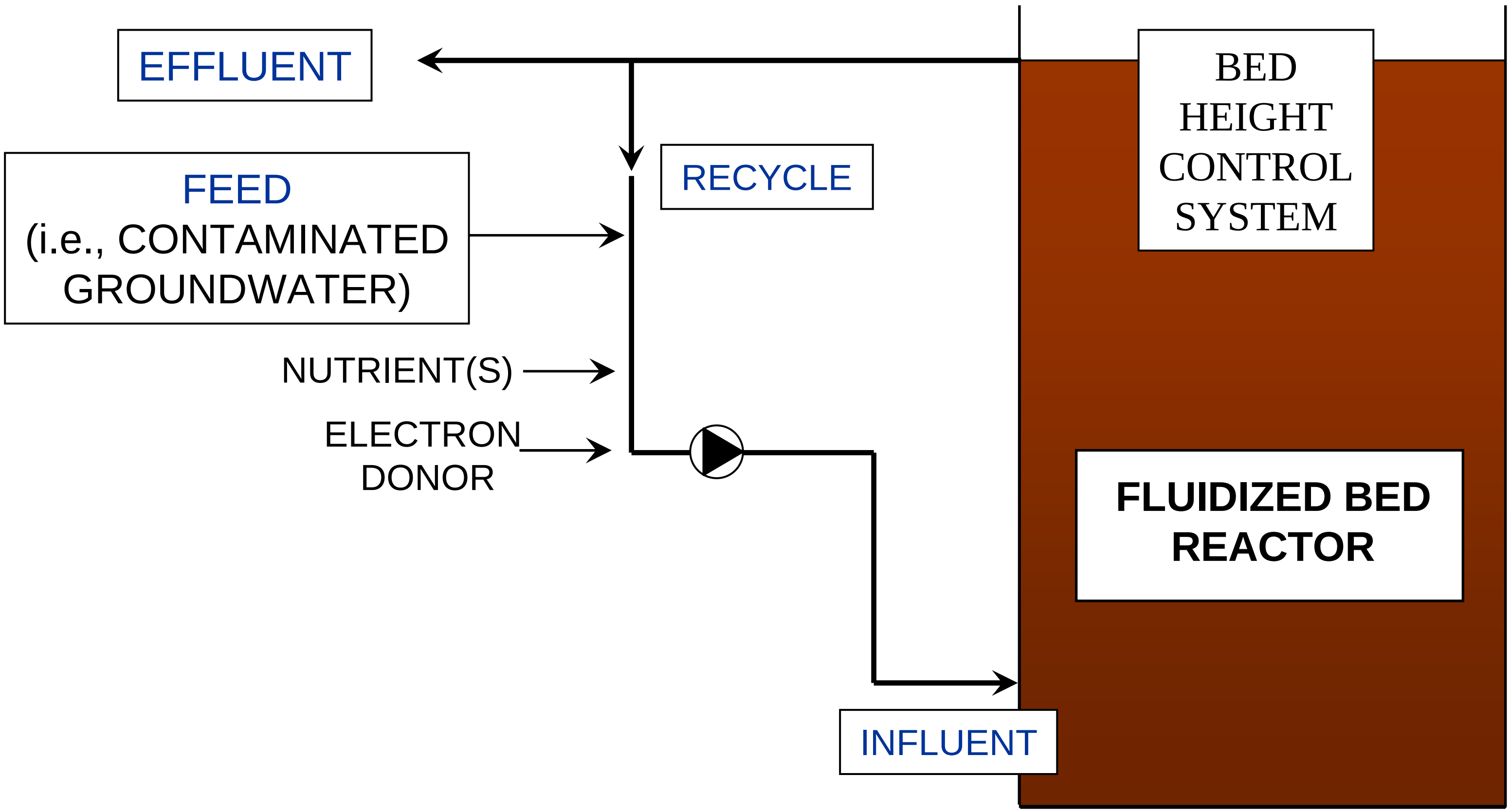
FBR Flow Schematic



FBR Advantages

- **High biomass concentration means long SRT and short HRT**
- **High volumetric efficiency translates to compact system**
- **Simplicity of operation minimizes need for operator attention**
- **Small impact from changing feed conditions, as feed is combined with recycle before entering the reactor**

Key Mechanical Components

- **Device and method used to distribute influent flow to the reactor**
- **Device and method used to control the expansion of the fluidized bed due to biofilm growth**
- **Method to control electron donor dosage rate**

Pilot-Scale Laboratory Testing for Perchlorate

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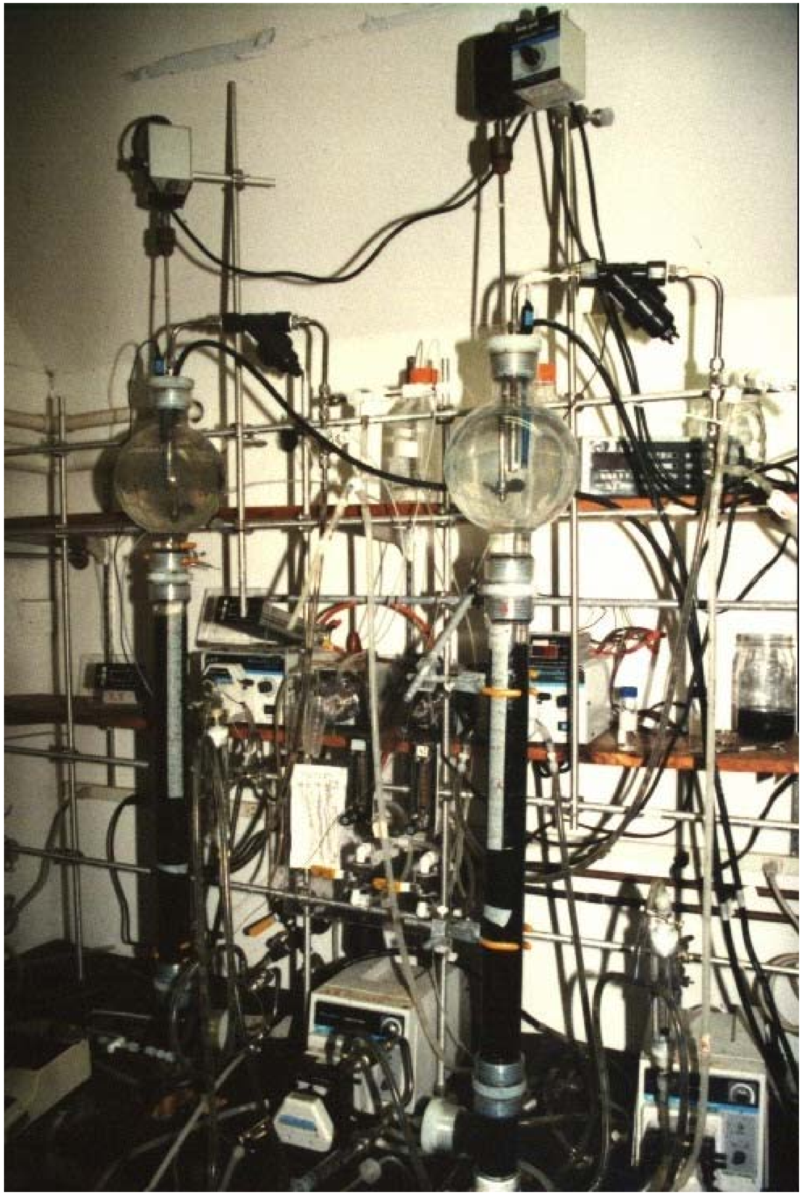

Laboratory-Pilot FBR

- **Treatability**
  - **Application:** Groundwater treatment
  - **Feed:** 6-10 ppm $C1O_4$, 1-2 ppm NO_3-N
  - **Effluent:** < 4 ppb $C1O_4$ (NO_3-N not measured)

- **Treatability**
  - **Application:** Groundwater / Process water
  - **Feed:** 400 ppm $C1O_4$, 480 ppm $C1O_3$, 20 ppm NO_3-N
  - **Effluent:** < 0.02 ppm $C1O_4$, < 1 ppm $C1O_3$ < 1 ppm NO_3-N

Laboratory-Pilot FBR

- **Application:** **Media Comparison, sand vs. GAC**
- **Feed:** **20-25 ppm ClO_4**
- **Effluent:** **< 4 ppb ClO_4**

- **Application:** **Electron Donor Comparison (Ethanol, Methanol, Acetate)**
- **Feed:** **20-25 ppm ClO_4**
- **Effluent:** **< 4 ppb ClO_4 (EtOH), < 20 ppb (HAc), ~1 ppm (MeOH), < 4 ppb (EtOH/MeOH)**

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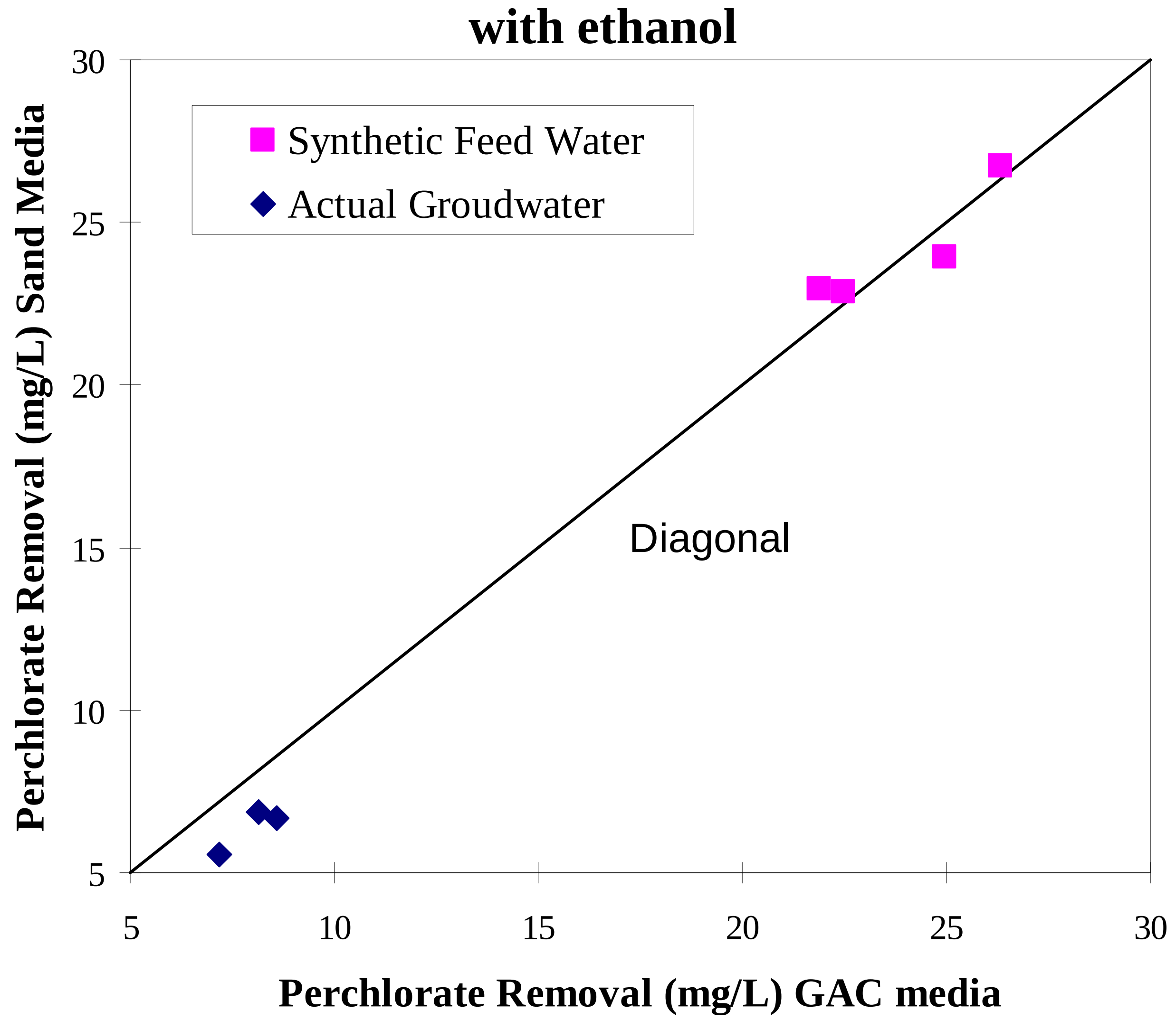
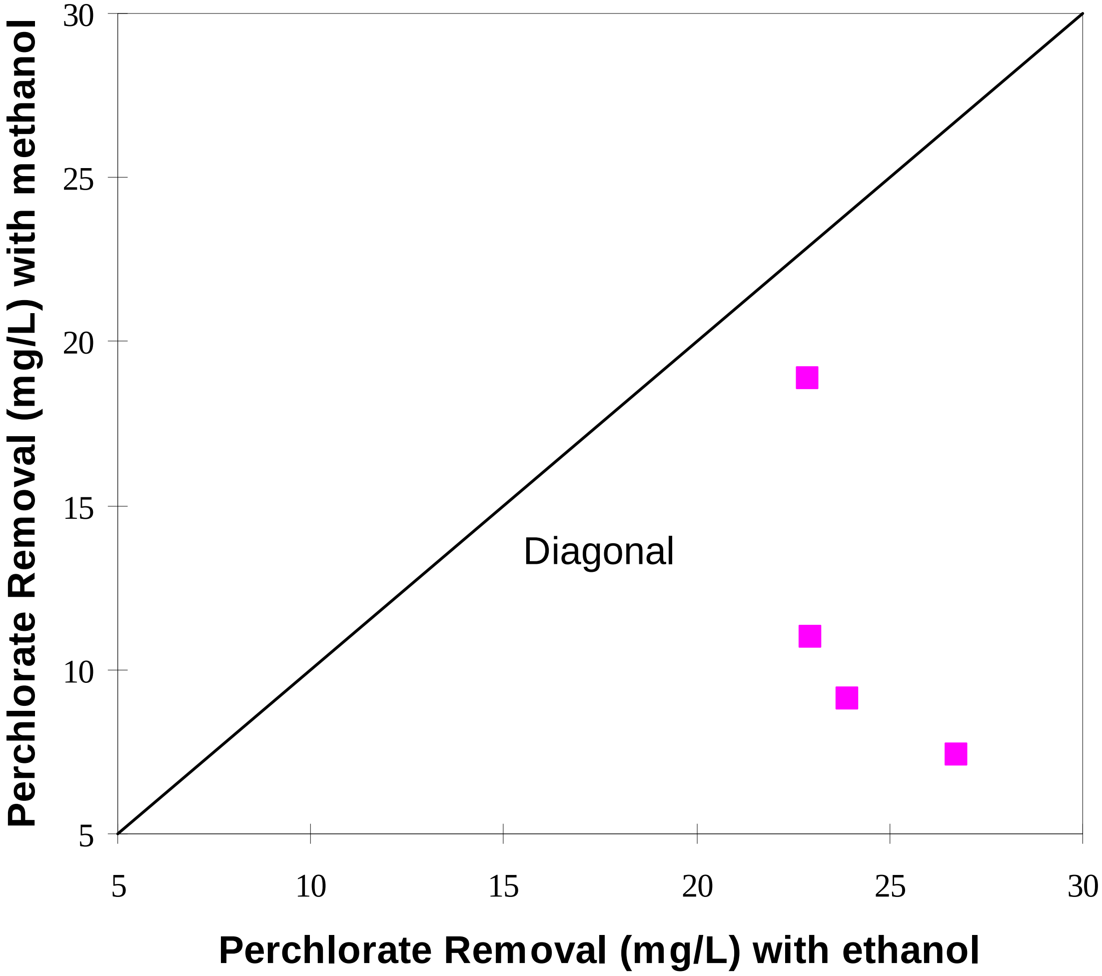
FBR Media Performance Comparison



Electron Donor Performance Comparison

with silica sand FBR media



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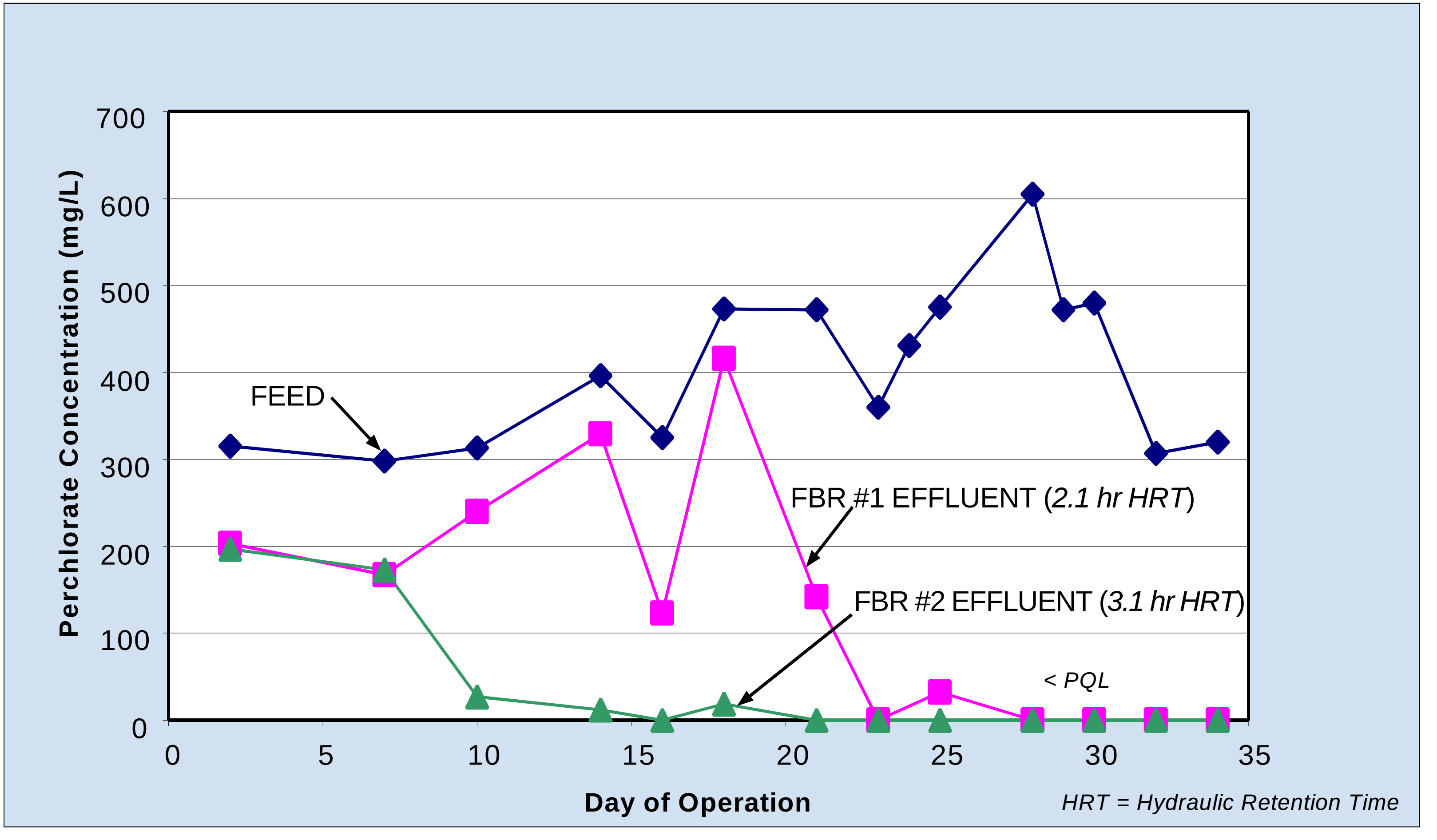
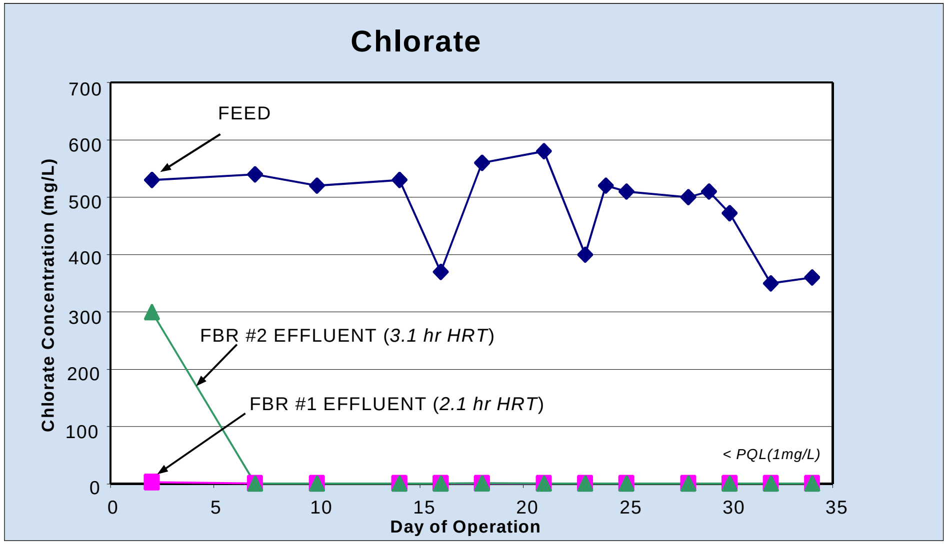
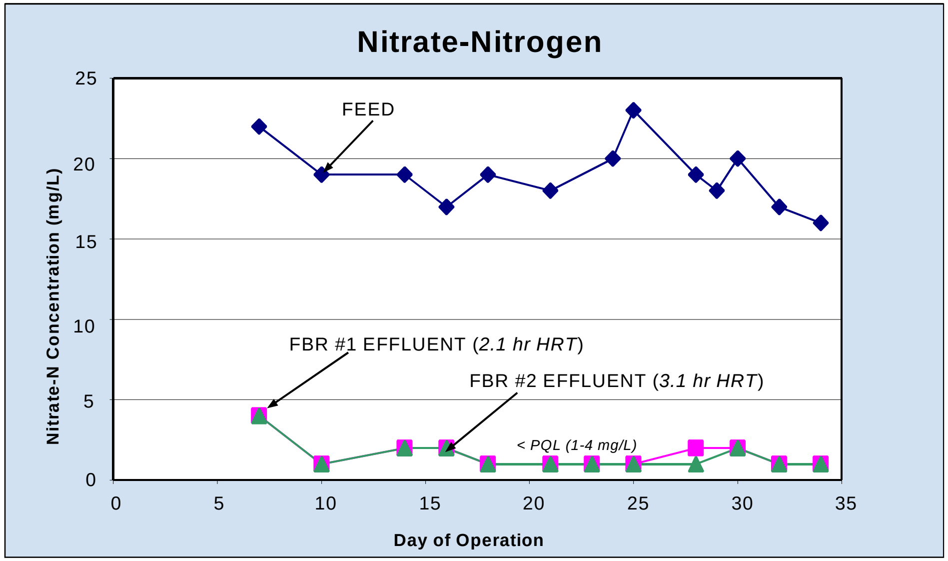
Treatment of High Concentration Perchlorate Waters using Pilot FBRs



Treatment of Chlorate and Nitrate in Pilot FBRs





Full-Scale
FBR Treatment
of
Perchlorate

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Full-Scale FBR Installation
(Perchlorate Reduction)

- Design Basis
  - 4,000 gpm
  - Four reactors
  - Ethanol as electron donor
  - GAC media
  - Volumetric ClO_4 loading = 44 lb/day/kcf

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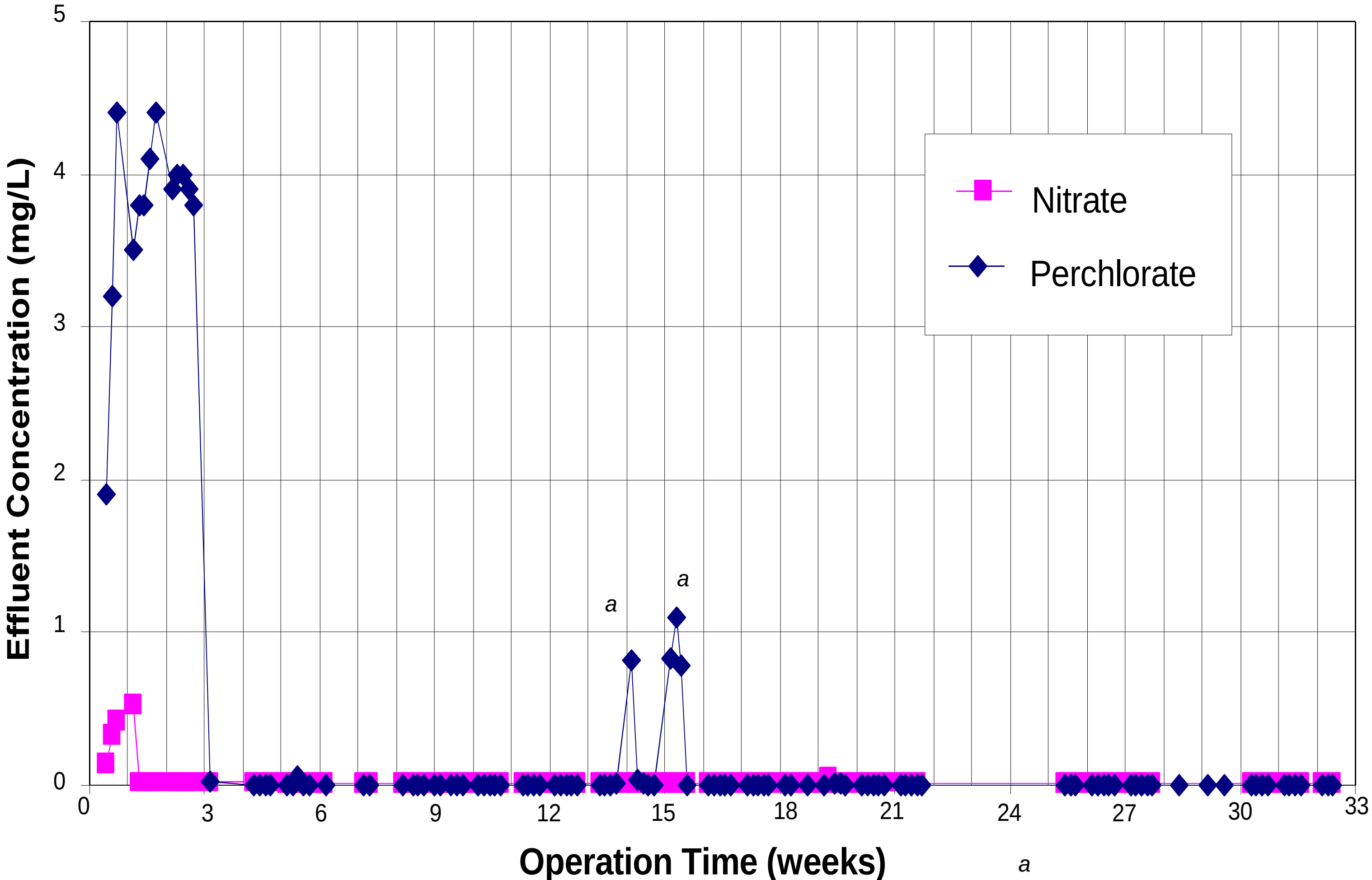
Full-Scale FBR Performance



a Insufficient ethanol dose during system tests.

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Summary

- GAC media yielded quicker startup and showed more resiliency than sand.
- Ethanol is a more effective electron donor than methanol.
- Biological treatment to below quantitation limits has been demonstrated for high and low concentration waters.
- Consistent treatment of perchlorate to below quantitation limits has been demonstrated in a full-scale FBR system for more than 1 year.

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