Ex-Situ Biological Treatment of Perchlorate in Groundwater

Brendan Robinson, P.E. (ERM)

Todd J Slater (Retia USA LLC)

Kevin Deeny (KC Environmental)

Jacob Barnes (ERM)

Presented by Kevin A. Morris (ERM)

Agenda

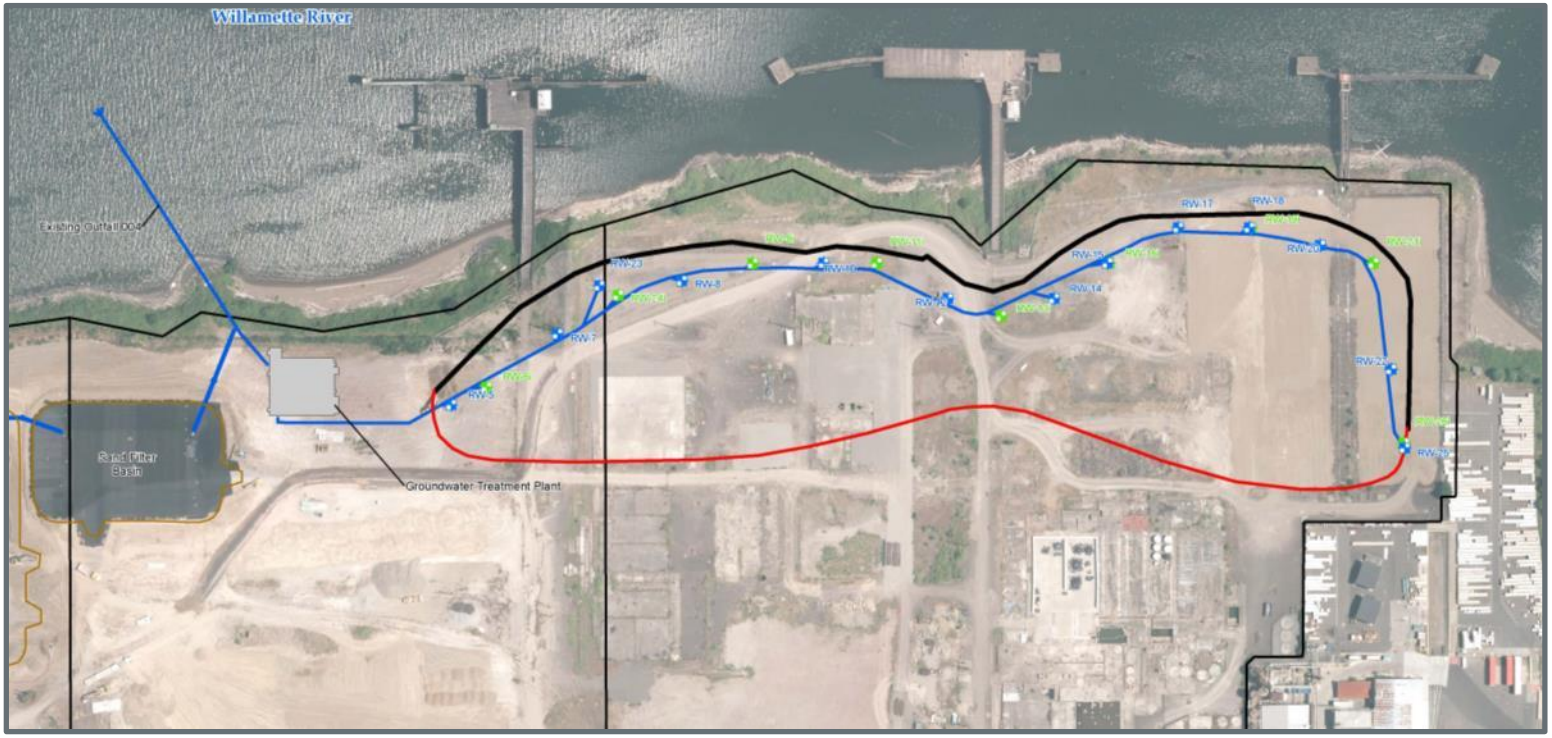
- Site Background
- Groundwater Source Control Measure (GW SCM)
  - Groundwater Barrier Wall (GWBW)
  - Groundwater Extraction and Treatment System (GWET)
- Fluidized Bed Reactor (FBR) System
  - Perchlorate reduction
- FBR historical and current performance
- Plan for increasing treatment rate to support overall GW SCM objective

Site Background

- Former Arkema chlor-alkali facility
- Adjacent to Portland Harbor Superfund Site
- Manufacturing operations from 1941 to 2001 (inactive facility)
- Investigations began in 1998 under ODEQ oversight
  - Voluntary Cleanup Agreement (1998)
  - Consent Order for Source Control Measures and Feasibility Study (2006)

Groundwater Source Control Measure

- Groundwater Source Control Measure (GW SCM)
  - Groundwater Barrier Wall (GWBW) – 1,800 LF
  - Groundwater Extraction and Treatment System (GWET)
  - Discharge to Willamette River



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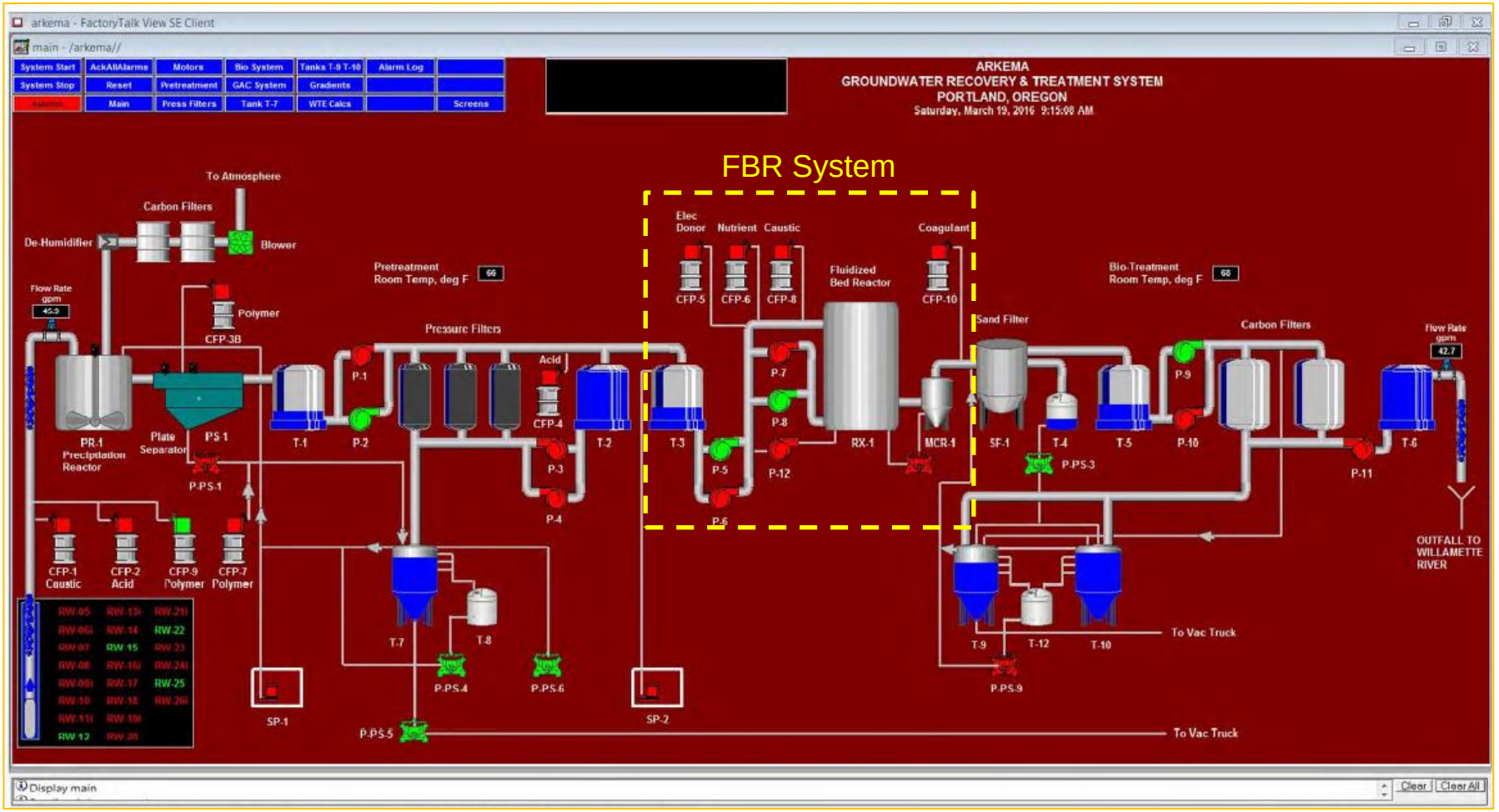
GWET System

- GWET System startup - March 2015
  - 109 GPM design flow rate
- Multiple treatment units
  - Chemical Precipitation
    - Hexavalent Chromium (Cr[VI])
    - Metals – Fe, As, Cd, Cr, Ni
  - Fluidized Bed Reactor (FBR)
    - Inorganics – Perchlorate, Chlorate
  - LGAC Polishing
    - Pesticides – DDT, DDE, DDD, Chlordane, Lindane
    - VOCs – Chlorobenzene, Chloroform, PCE, Benzene

GWET System Process Flow



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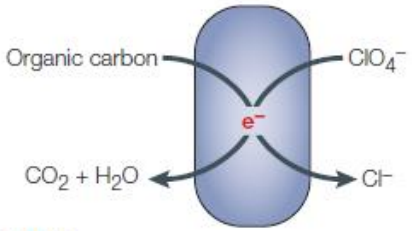
Microbial Perchlorate Reduction

Perchlorate reducing bacteria

- Oxidize organic carbon
- Food source (electron donor)
- CO_2, H_2O, and Cl^- are produced
- Sequential degradation
- Bacteria are diverse and ubiquitous

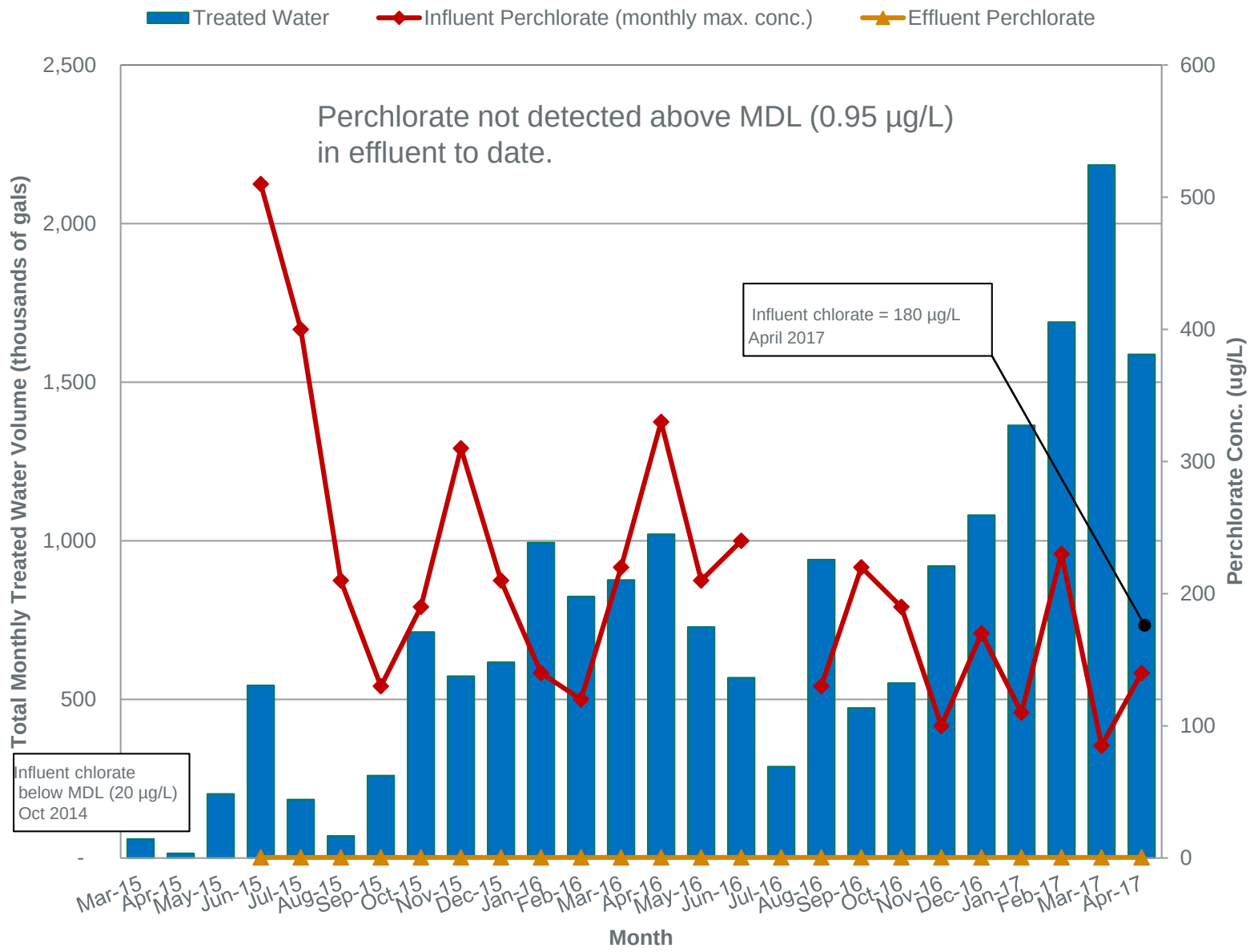


***Dechlorospirillum* strain WD**

***Dechloromonas* strain RCB**

Microbial Perchlorate Reduction: Rocket-Fueled Metabolism
John D. Coates and Laurie A. Achenbach
Nature Reviews, Microbiology, Volume 2, July 2004

Monthly Treated Volume and Perchlorate



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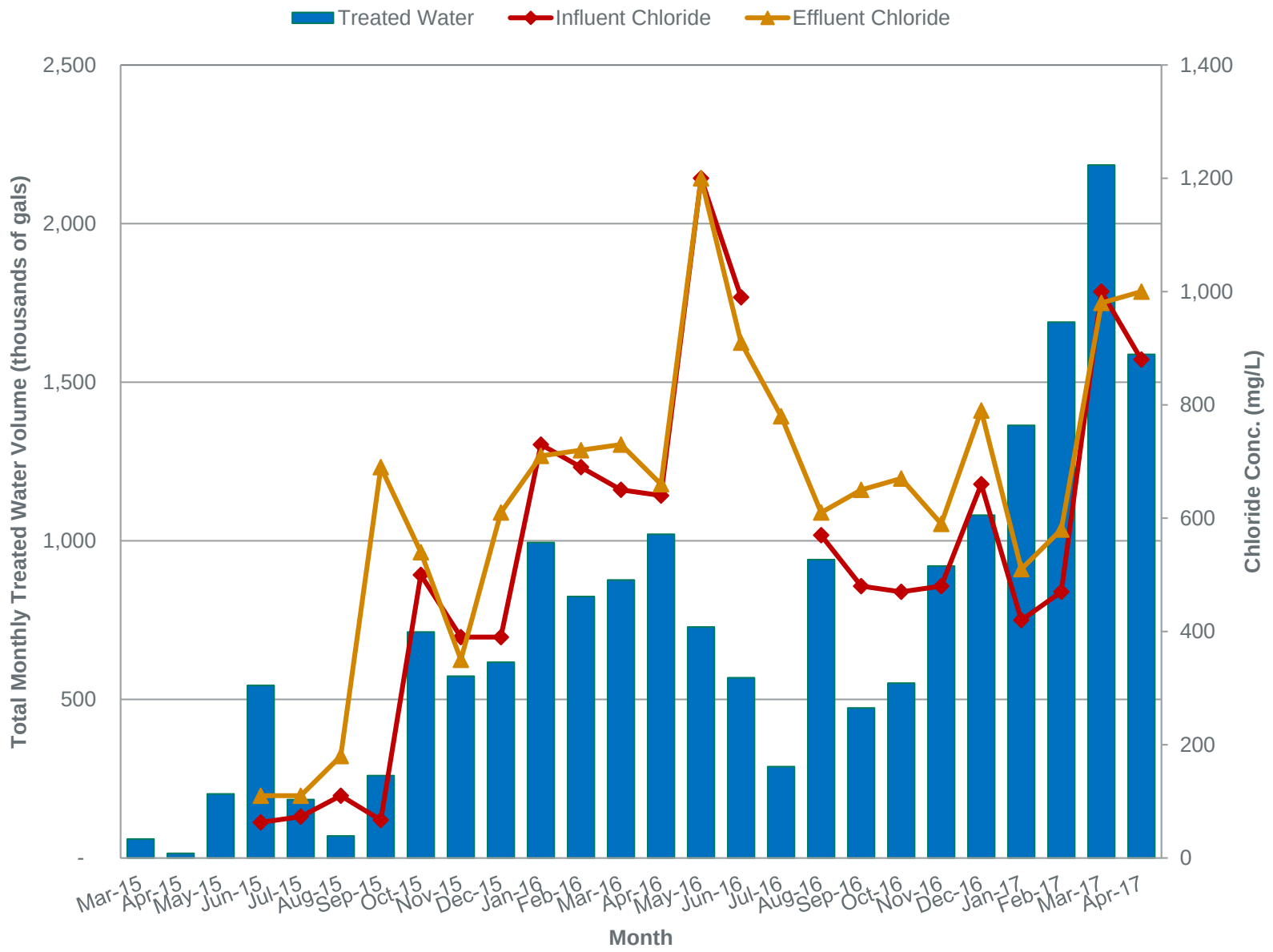
GWET Influent and Effluent Chloride



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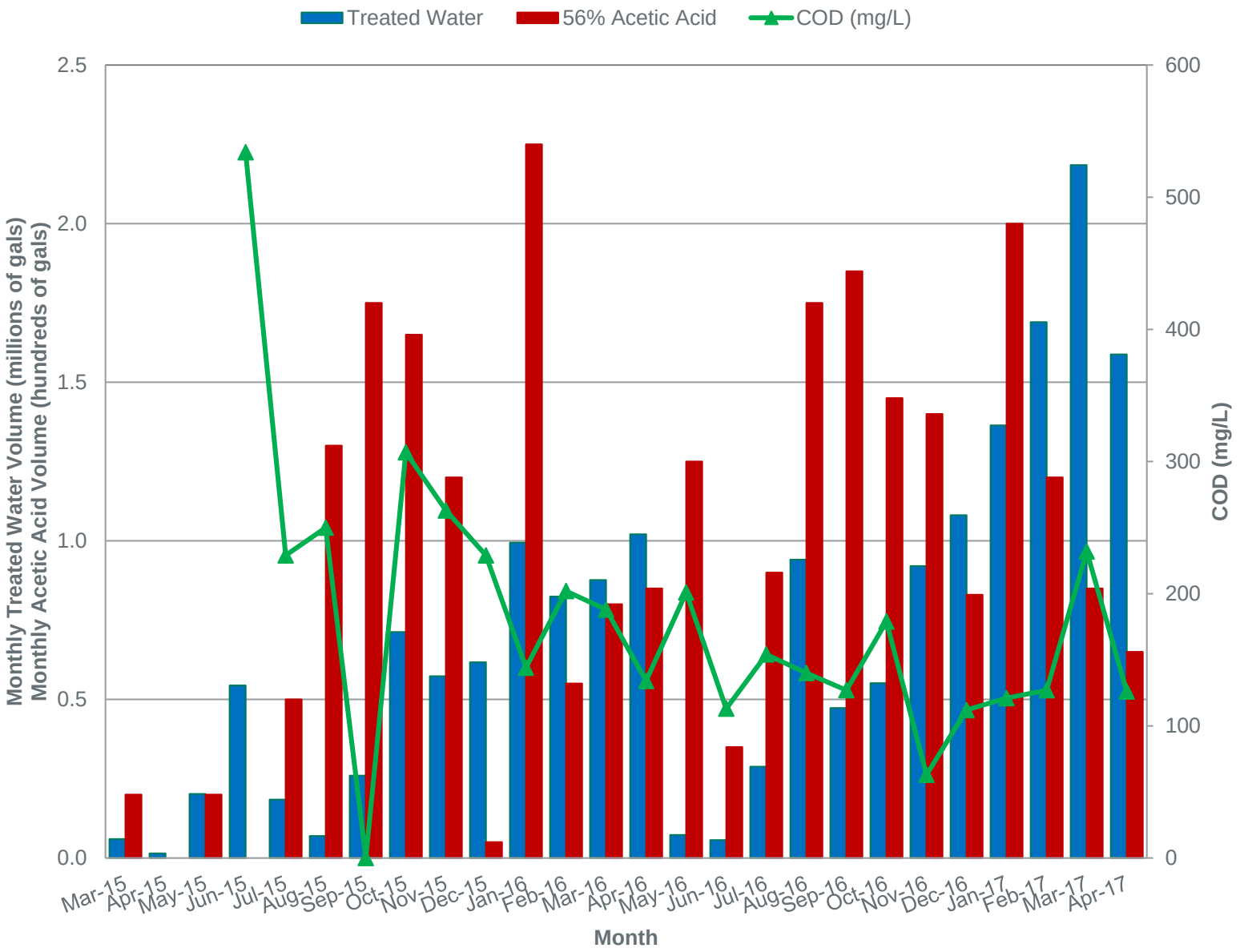
Electron Donor, Nutrients, and pH

- Organic Carbon Food Source
  - 56% acetic acid solution (electron donor)
    - Adjusted to target residual chemical oxygen demand (COD)
    - 3 gallons per day
- Nutrients
  - 85% phosphoric acid solution
    - Naturally occurring phosphorous
  - Urea (46% urea nitrogen)
    - Ammonia nitrogen in solution
    - Approximately 12 pounds per day
- pH Control
  - 25% caustic soda solution
  - Maintain pH of ~ 7.00

FBR Electron Donor and Residual COD



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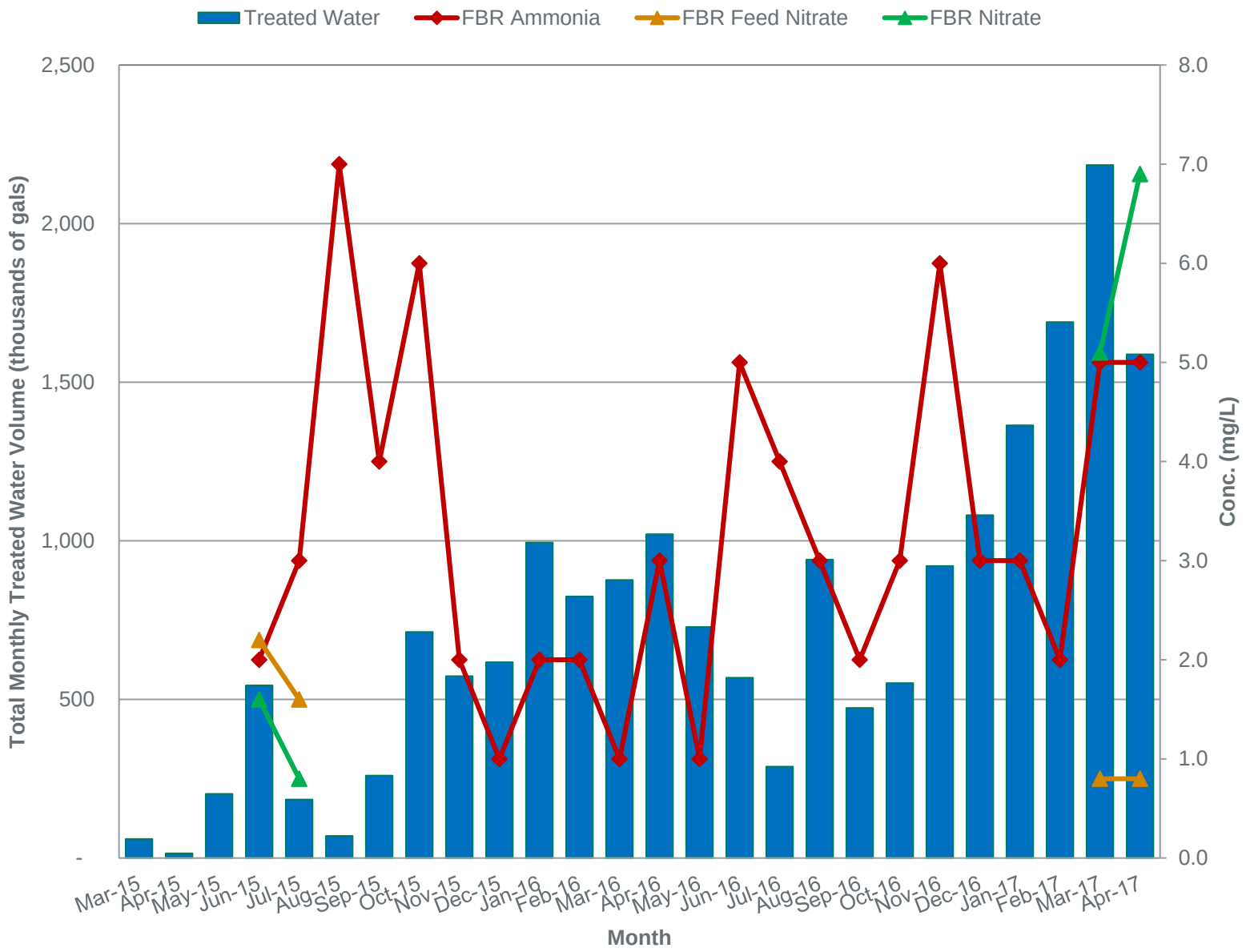
FBR Ammonia and Nitrite/Nitrate



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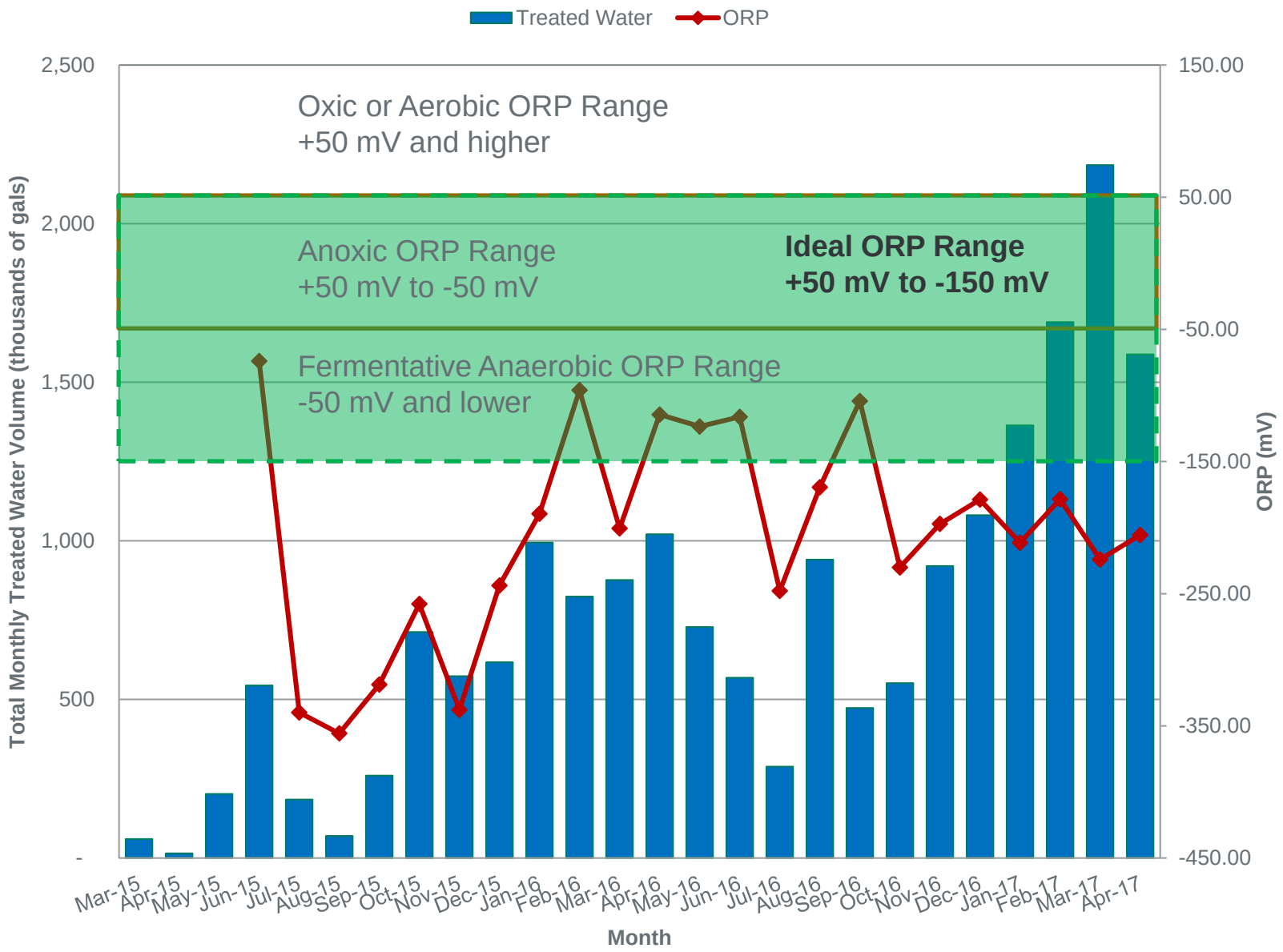
Nitrification and Denitrification

- Some ammonia nitrogen from urea converted to nitrite and nitrate
  - Biological nitrification process
  - Generally only occurs in the presence of excess oxygen
- Nitrite/nitrate is removed by Denitrification
  - Occurs without oxygen
  - Competes with reactions that decompose perchlorate
- Presence of nitrite/nitrate suggests nitrification, but limited denitrification
- Limited denitrification suggests a decrease in perchlorate reducing reactions
  - Decrease in denitrifying microbial population

FBR Oxidation-Reduction Potential (ORP)



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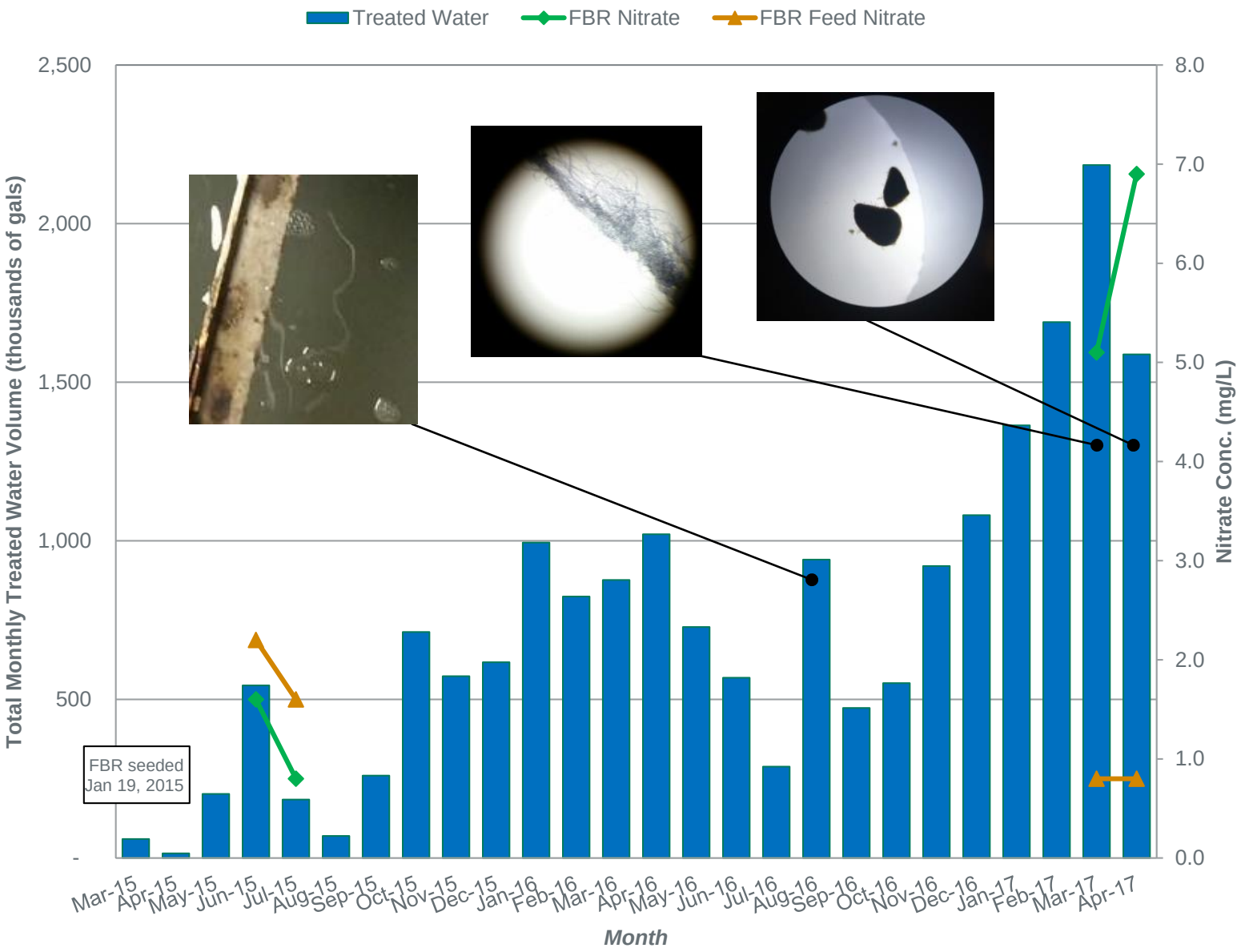
Microscopic Investigation



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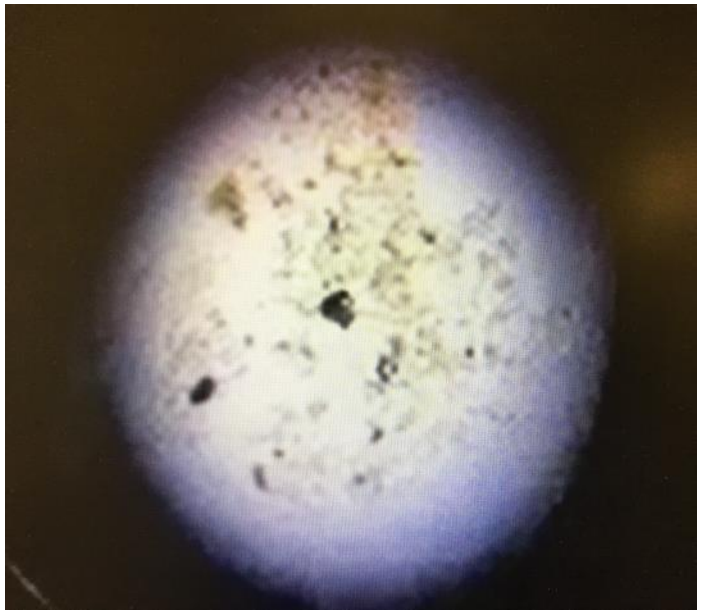
Current Steps

- Current conditions
  - Nitrification with limited denitrification
  - Low ORP (below -200 mV)
- Re-Seeded FBR with 200 gals treated sewage sludge from local POTW (May 2017)
- Target operating conditions
  - Denitrification
  - +50 to -150 mV ORP range
  - Consumption of TOC and COD in FBR (monitor influent and effluent)



Conclusion and Path Forward

- FBR System is very robust
  - Successful treatment even in non-ideal conditions
  - Treats wide range of perchlorate concentrations to ND
    - Up to 5,000 µg/L (Design)
    - Highest influent = 510 µg/L
    - Not detected above MDL (0.95 µg/L) in effluent
- Plan forward
  - Re-Seeded FBR May 2017 to restore healthy microbe population
  - Increase treatment rate to support overall GW SCM objective
    - Hydraulic control of impacted groundwater
    - Well field enhancement 46 gpm (current) to 80 gpm

Questions?