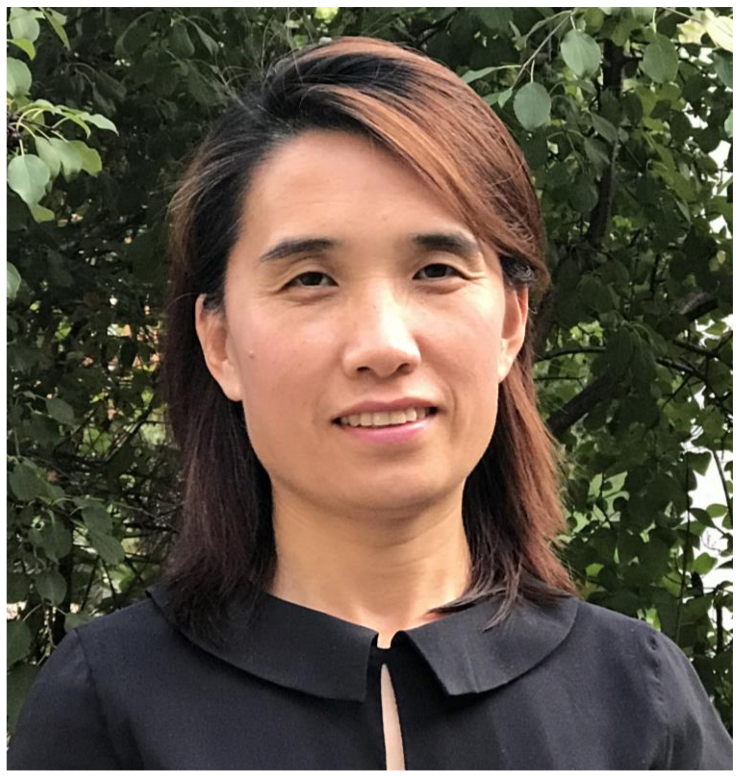
Metropolitan Water Reclamation District of Greater Chicago

Welcome to the September Edition of the 2022 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' audio lines have been muted to minimize background noise. For attendees in the auditorium, please silent your phones.
- A question and answer session will follow the presentation.
- For remote attendees, Please use the "**Chat**" feature to ask a question via text to "**Host**". For attendees in the auditorium, please raise your hand and wait for the microphone for asking a verbal question.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar has been approved by the ISPE for one PDH and approved by the IEPA for one TCH. Certificates will only be issued to participants who attend the entire presentation.

Dr. Dongqi (Cindy) Qin
Senior Environmental Research Scientist



Cindy Qin has been with the Metropolitan Water Reclamation District of Greater Chicago for over 13 years. She is a Senior Environmental Research Scientist in the Capital Planning, Wastewater Research and New Technology Section of the Monitoring and Research Department's Environmental Research and Monitoring Division. Cindy has a Bachelor of Science and Master of Science in chemistry from Jilin University, Changchun, China and received her Ph.D. in polymer chemistry and physics from Beijing University, Beijing, China. Prior to joining the District in 2009, Cindy worked on research projects at various universities in the U.S. and China.

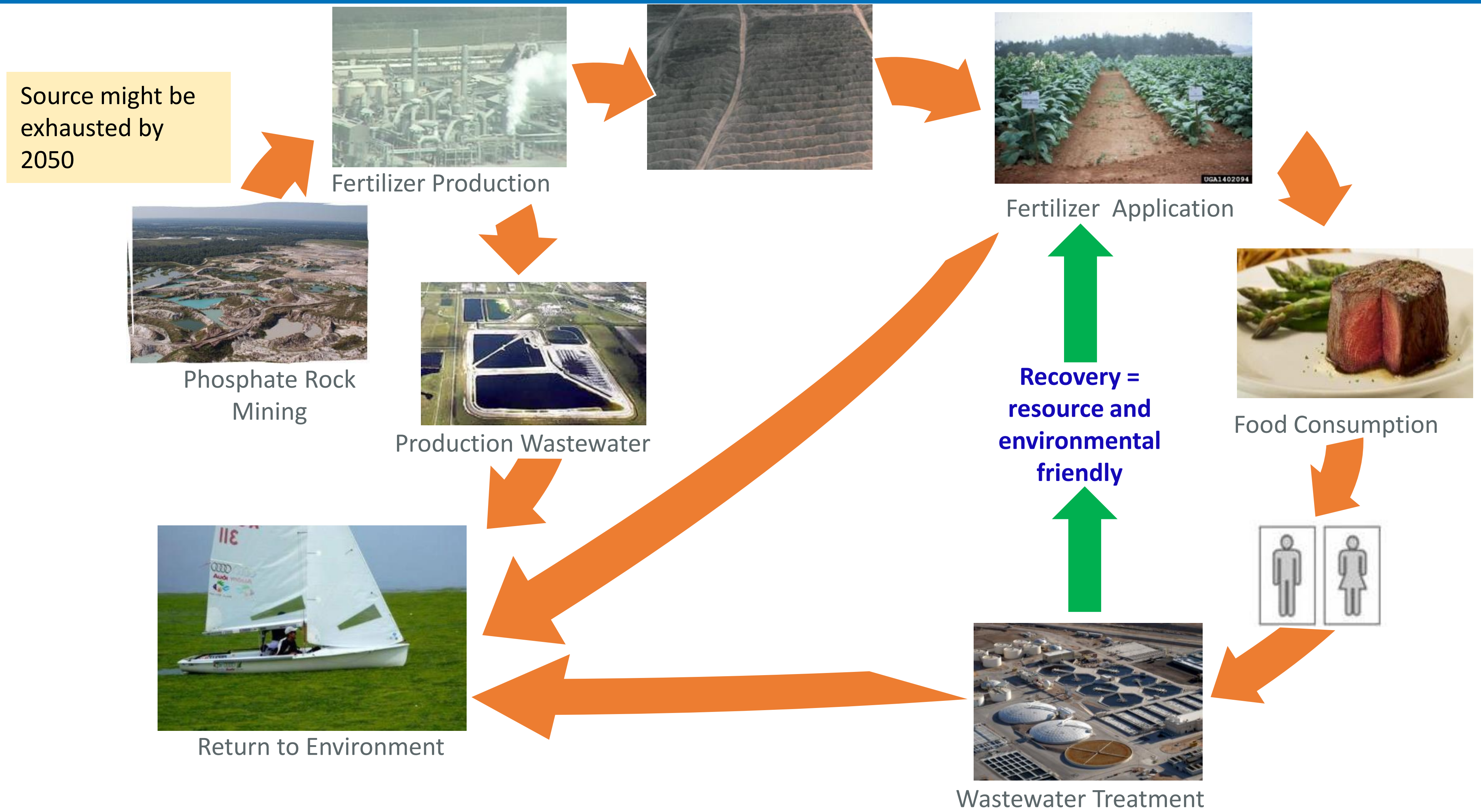
Side-stream Enhanced Biologic Phosphorus Removal (S2EBPR) Pilot Test at the Calumet Water Reclamation Plant

September 30th, 2022


Outline

- Overview
  - The District and Calumet WRP
  - Calumet WRP P Removal Road Map
  - Understanding Side-stream Enhanced Biological Phosphorous Removal (S2EBPR)
- Calumet Battery A S2EBPR Pilot Results
- Findings and Next Step
- Acknowledgements

Phosphorus “Life Cycle”: Current to Future



State and Federal Nutrient Standards Development

1998
USEPA initiated nutrient criteria development

2000
IEPA requested to develop nutrient standards for the state

2000
USEPA finalized 14 ecoregional nutrient criteria recommendations for streams and rivers

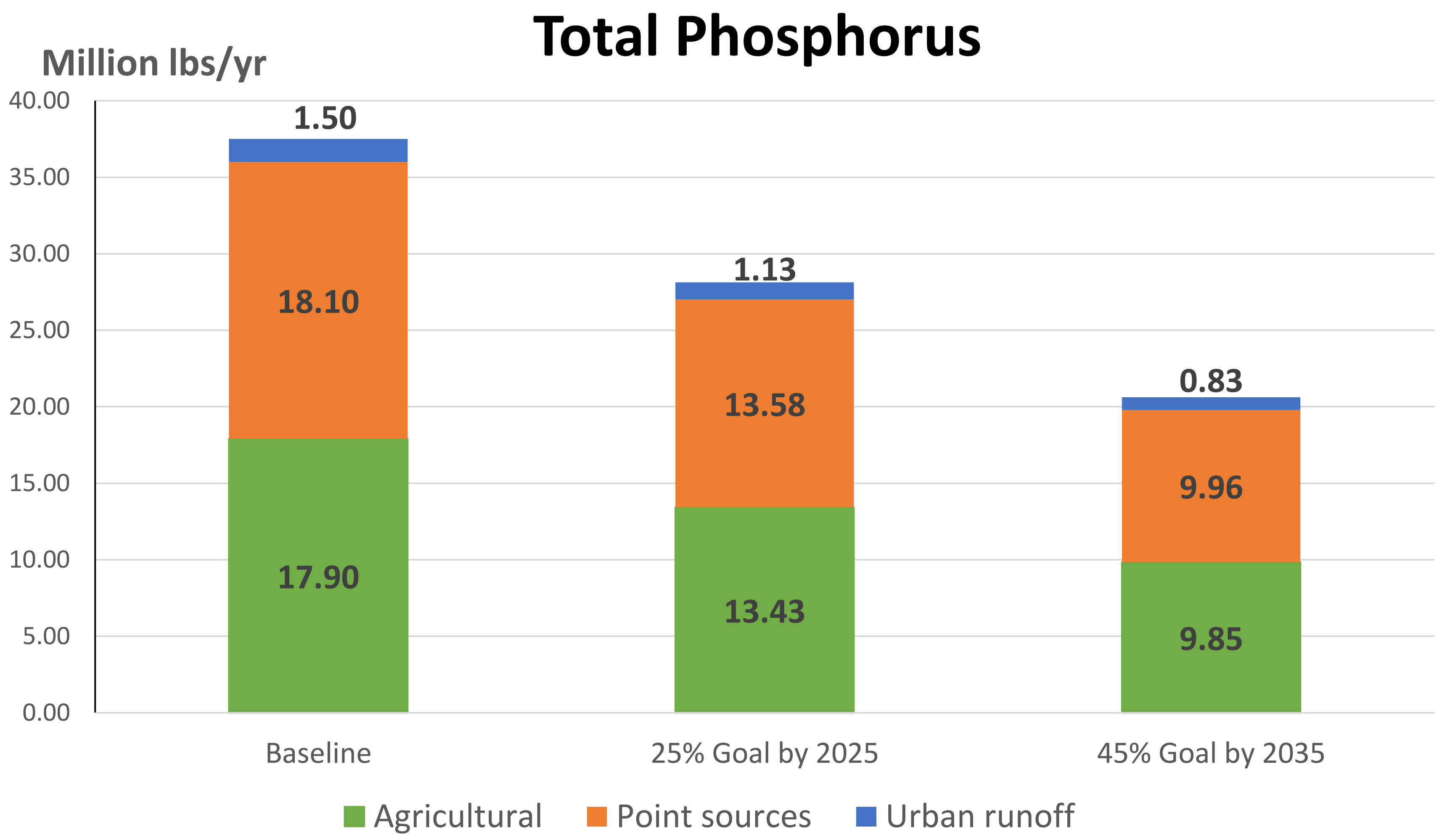
2006
IEPA/IPCB promulgated the Interim P Rule

(1 mg/L TP as monthly average for new and expanding WWTPs)

2011
IEPA renewed its efforts to develop nutrient standards with 4 working groups

2015
IEPA finalized the Illinois Nutrient Loss Reduction Strategy

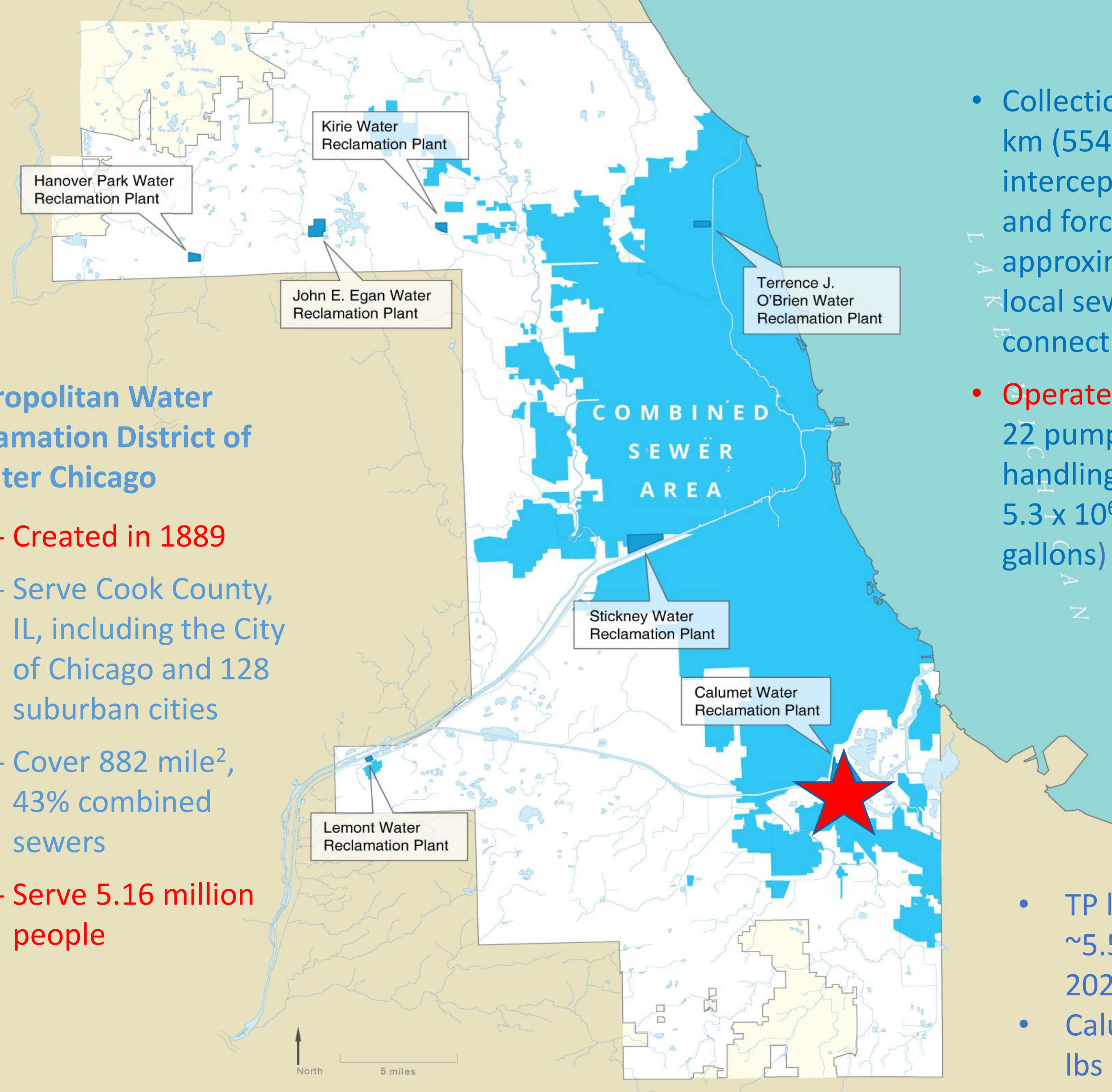
Illinois Nutrient Loads at baseline and 45 Percent Reduction Goal*



*Data obtained from ILNR strategy

Metropolitan Water Reclamation District of Greater Chicago

- Created in 1889
- Serve Cook County, IL, including the City of Chicago and 128 suburban cities
- Cover 882 $mile^2$, 43% combined sewers
- Serve 5.16 million people



- Collection system: 891 km (554 miles) of intercepting sewers and force mains fed by approximately 10,000 local sewer connections
- Operates 7 WRPs and 22 pumping stations, handling daily flow of 5.3 x 10^6 m^3 (1.4 billion gallons)

- TP load discharged ~5.5 million lbs in 2021
- Calumet ~2.7 million lbs in 2021.

Calumet Water Reclamation Plant

- Serves over 1 million people
- Flows:
  - Avg Design Capacity: 354 MGD
  - Average 2021: 243 MGD
- Full nitrification
- 5 aeration batteries
  - 48 aeration tanks
  - Conventional one or two passes/tank
  - 52 circular secondary clarifiers

Calumet P Removal Roadmap

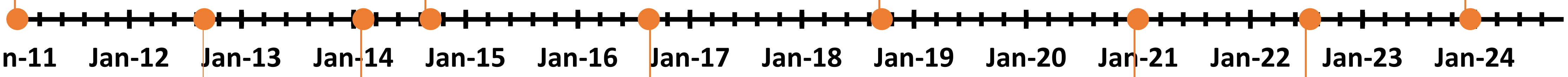
2011

- MWRD informed IEPA on steps:
  - To biologically remove P *using existing infrastructure*
  - Recover P where possible
  - To work within District's long term strategic plan on resource recovery and sustainability

Oct-Dec, 2014
Full-scale EBPR carbon study

2018-2019
SBR S2EBPR study

January 4, 2024
NPDES TP Permit Monthly average 1 mg/L



2012

- Formed a District-wide Phosphorus Task Force to study and implement of EBPR
- One battery EBPR study

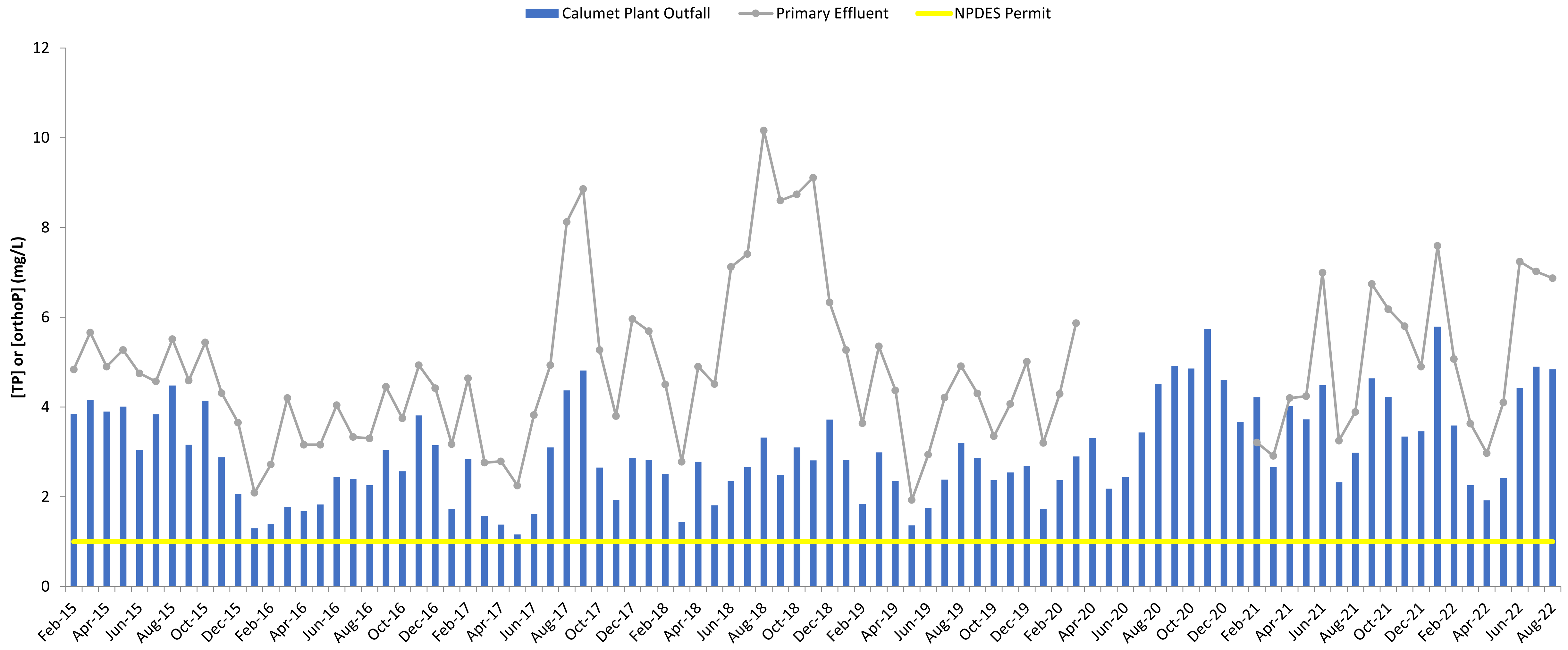
Spring, 2014
SBR EBPR carbon study

2016-2017
P Removal Modeling and Feasibility Study

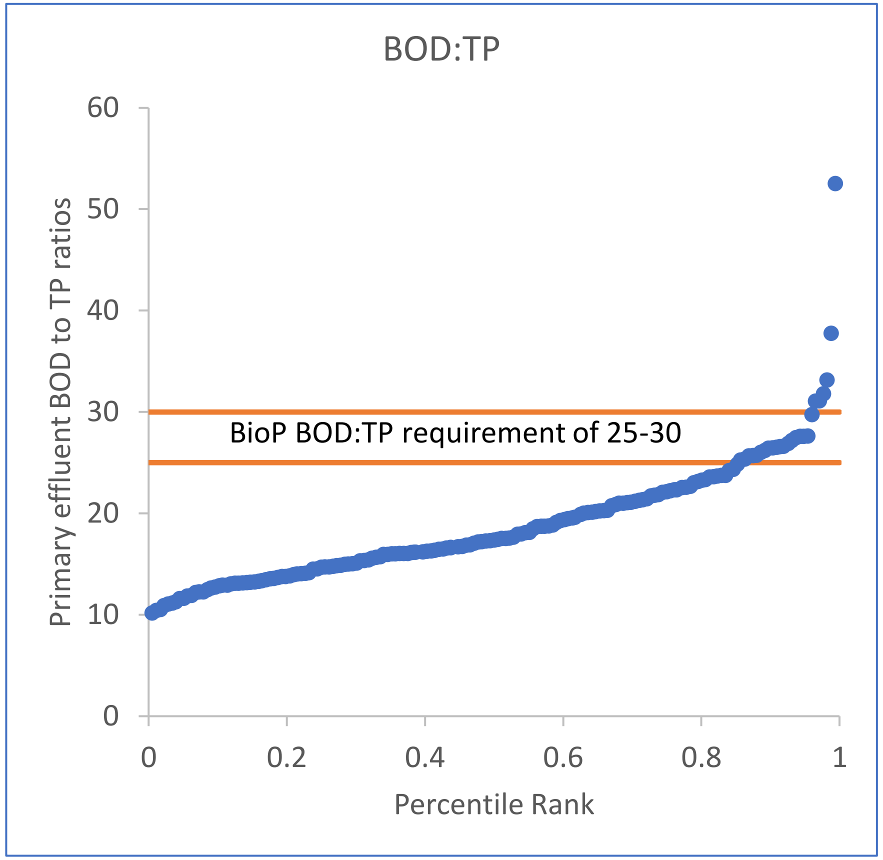
2021
Full-scale S2EBPR pilot

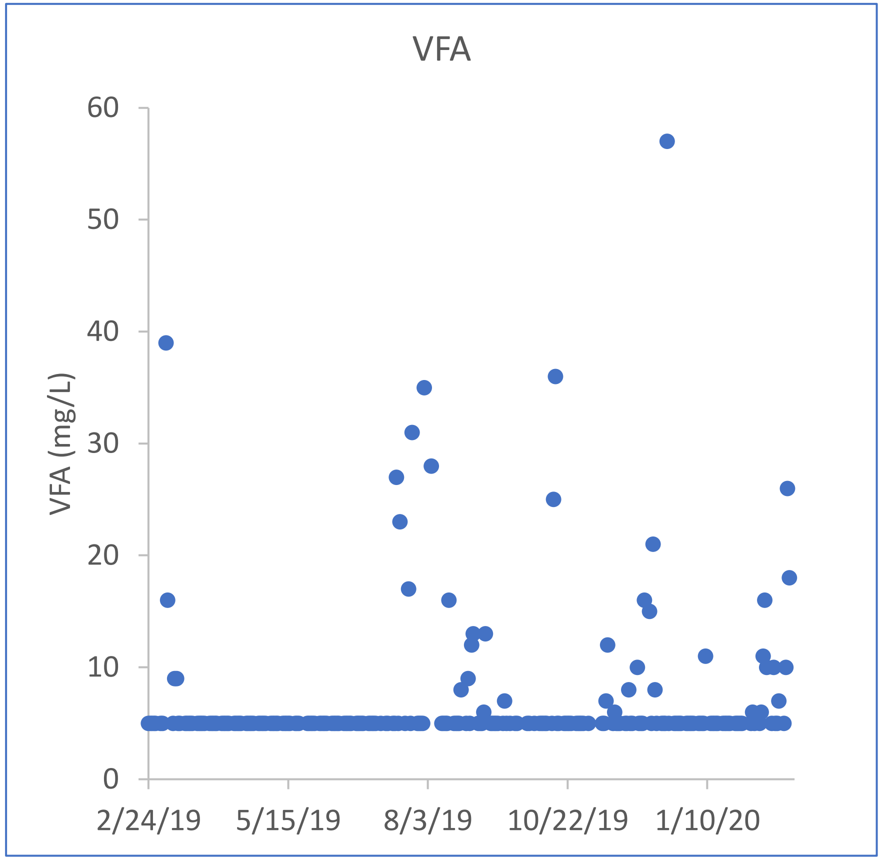
August 11, 2022
Contract 18-254-3P Awarded

Calumet Outfall and Primary Effluent Monthly Average TPs



Low Carbon Primary Effluent – Unfavorable to EBPR

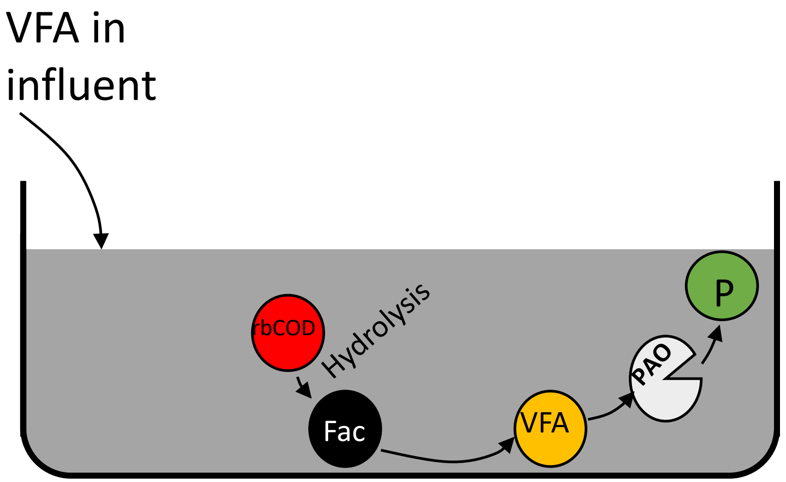




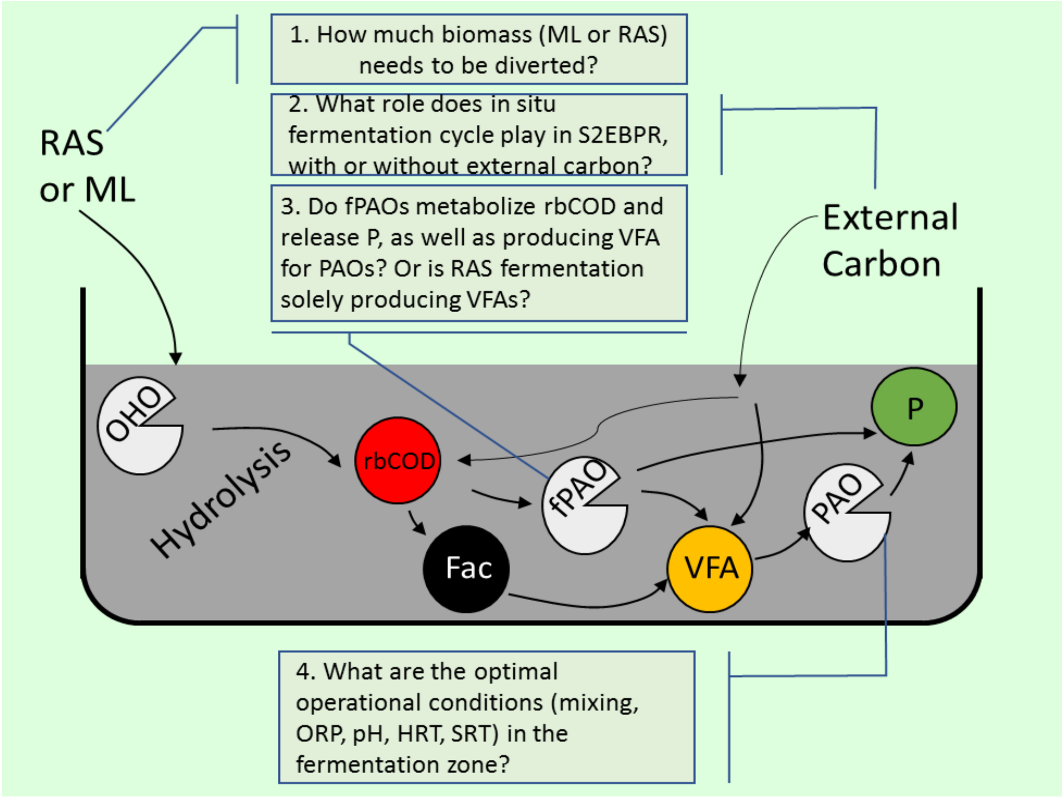
- The carbon to phosphorus ratio (C/P) is a general metric for determining EBPR potential
- Calumet WRP primary effluent is very carbon limited → 200,000 lbs/d COD deficit

Understanding S2EBPR

Conventional EBPR metabolism



Fermentative metabolism



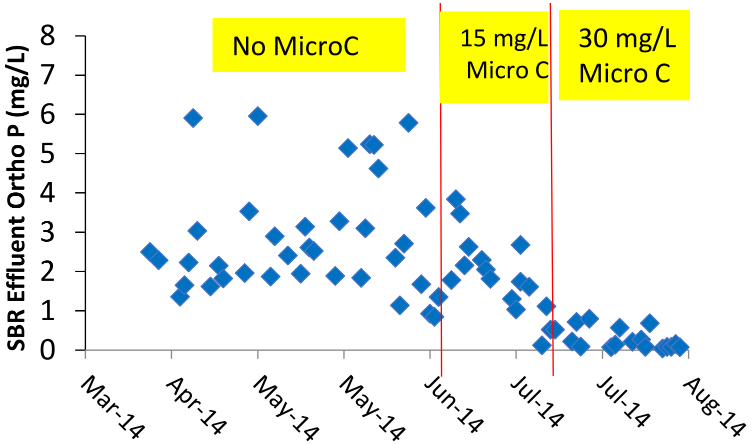
Motivations of using S2EBPR

- Stable anaerobic conditions reduce upsets
- Carbon production reduces reliance on influent characteristics
- Selective pressure leads to more effective use of carbon

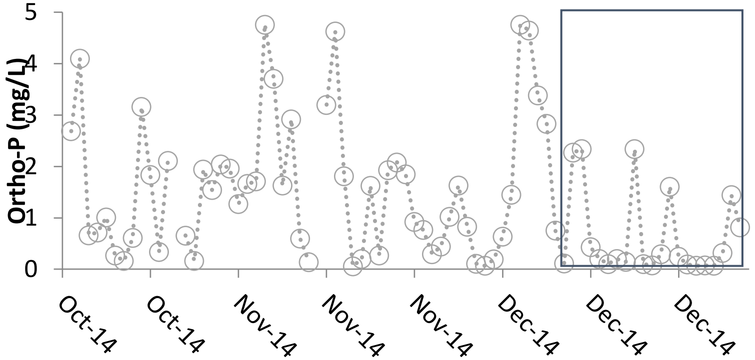
Credit to Black & Veatch for slide

Calumet Phosphorus Removal Past Studies

Spring, 2014
SBR EBPR carbon study



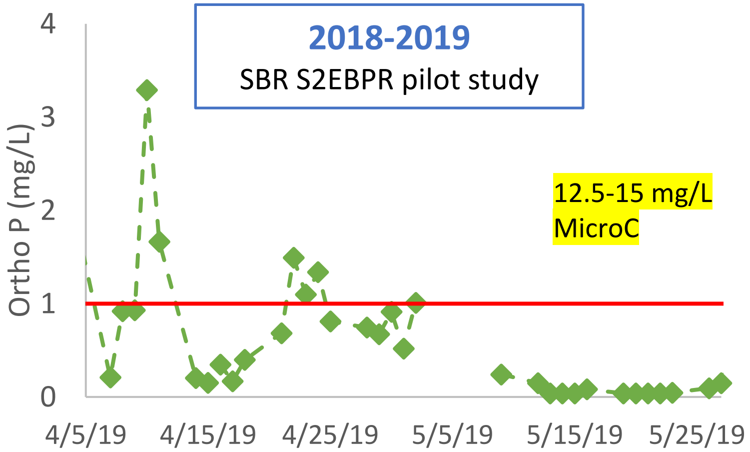
Oct-Dec, 2014
Full-scale EBPR carbon study



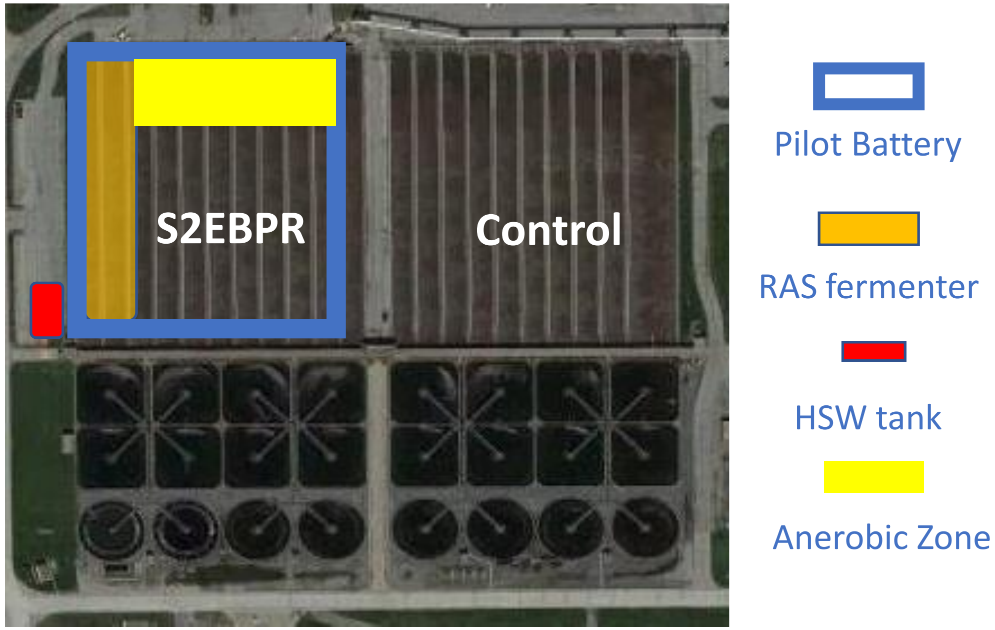
2016-2019
P Removal Modeling and Feasibility Study

- EBPR requires 200,000 lbs/d COD
- Chem P was recommended for all limit levels.
- S2EBPR process may decrease the O&M cost due to possible lower carbon needs.

2018-2019
SBR S2EBPR pilot study



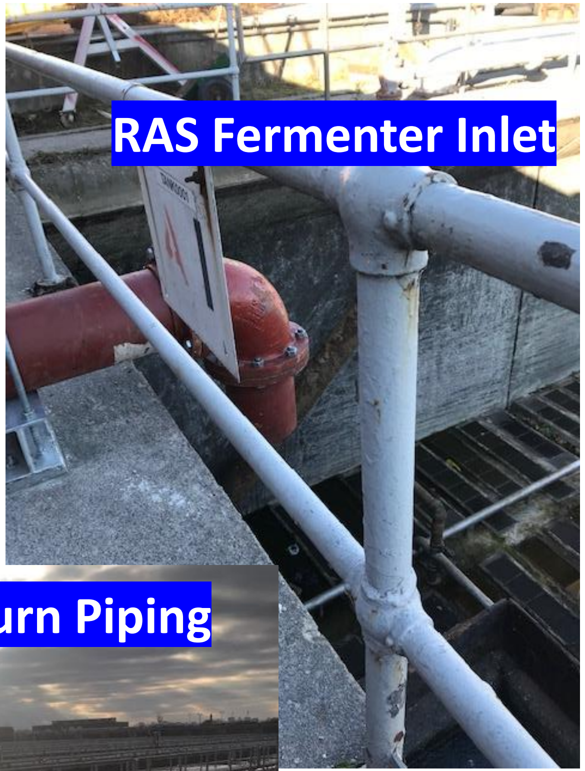
2021-2022
S2EBPR demonstration study



Calumet Battery A S2EBPR Pilot Pictures

RAS Fermenter w/ Mixers

External Carbon Dosing Pumps



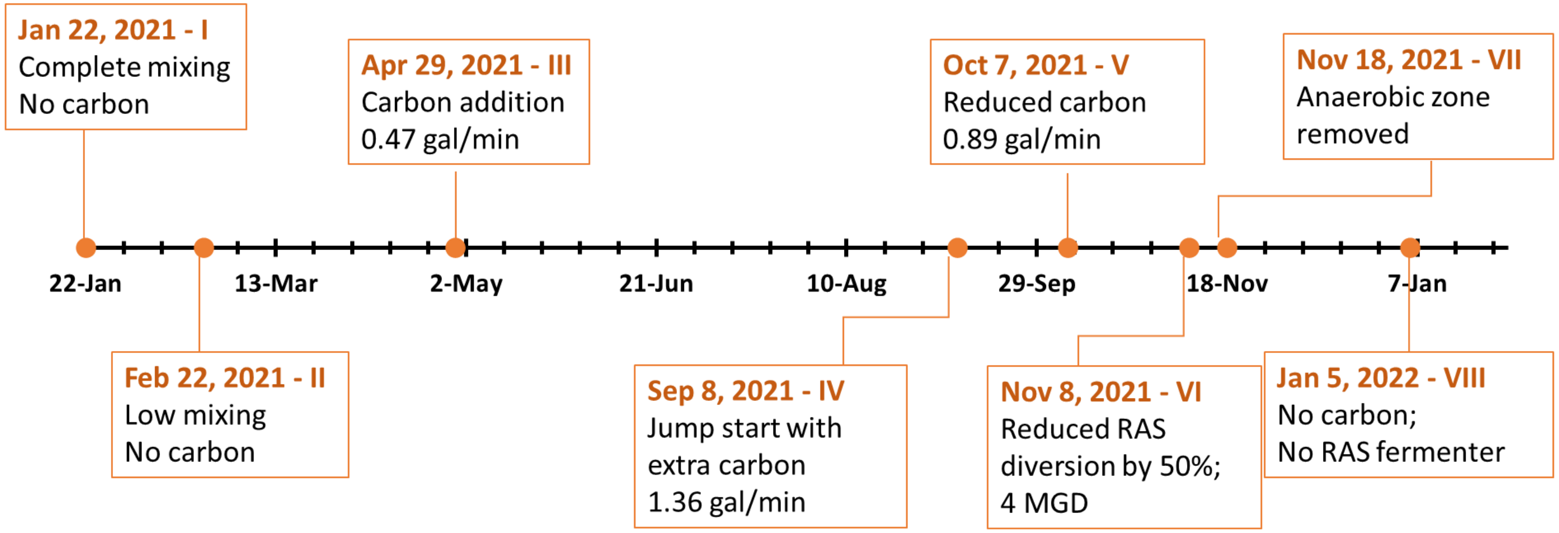
RAS Fermenter Inlet

Fermented RAS Return Piping

Calumet WRP S2EBPR Demonstration and Testing Scenarios

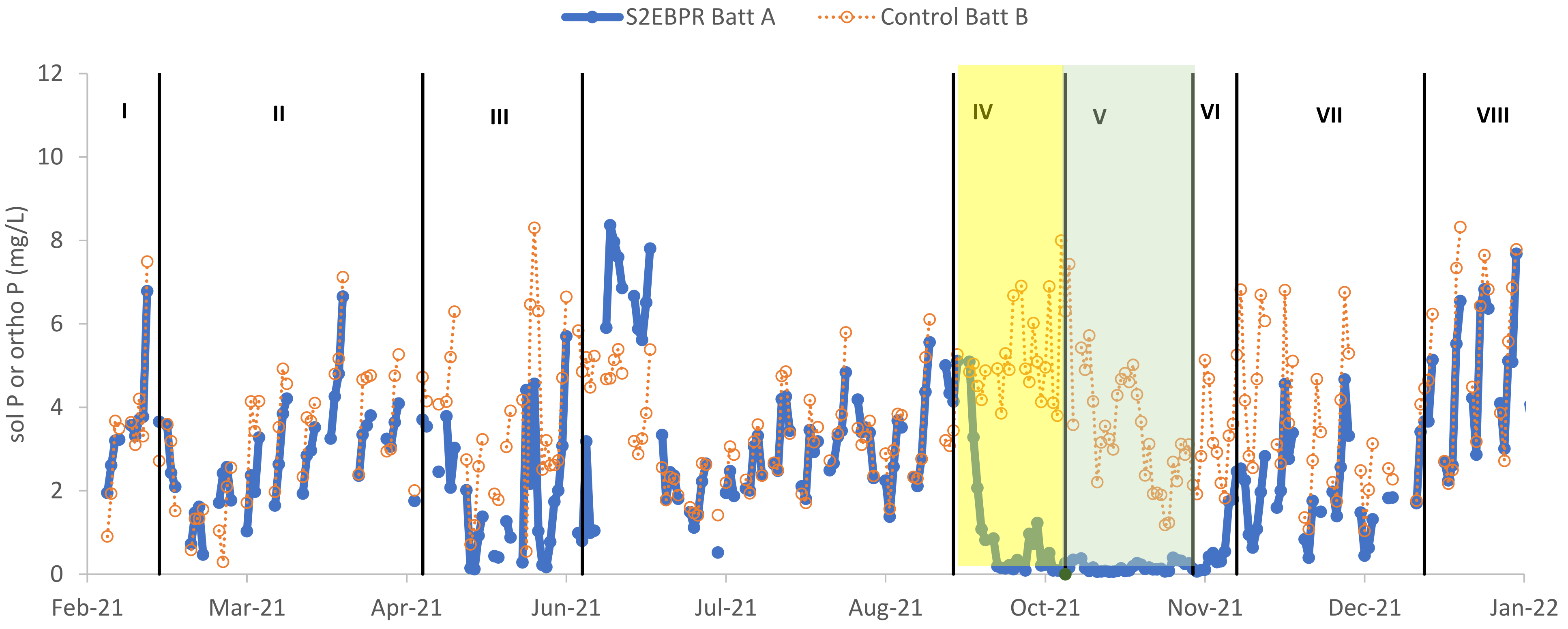
- Demonstration Project Description
  - Influent flow avg.: 46 MGD
  - RAS flow avg.: 38 MGD
  - RAS diversion: 4 or 8 MGD
  - HRT: 10 or 20 hours

- Drivers for S2EBPR
  - New effluent phosphorus limitation
  - Low plant influent organics unfavorable to conventional EBPR
  - Existing available tank volume for RAS fermenter
  - Possible lower chemical cost



- Testing Scenarios:
  - Fermenter mixers (complete mixing *vs.* low mixing and daily bumping)
  - External carbon addition (Jump-start with high carbon dosage, step decrease till no carbon addition)
  - RAS diversion rate percentage
  - With and without mainstream anaerobic zone

Calumet WRP S2EBPR Pilot Performance – Daily Effluent P

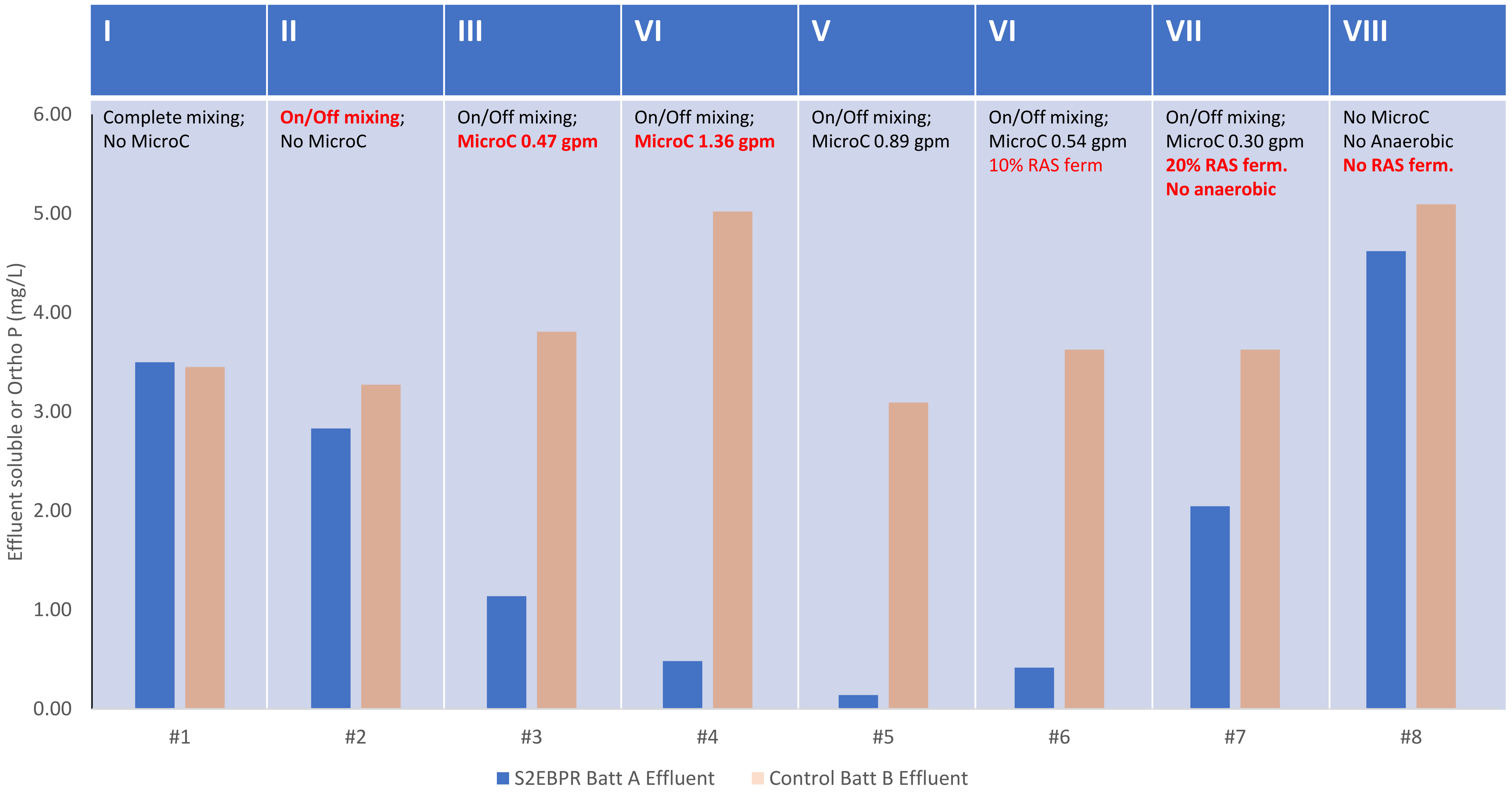


- 20% RAS except VI w/ 10% and VIII 0%
- MicroC additions in III-VII
  - Underdosed in III, VI, & VII

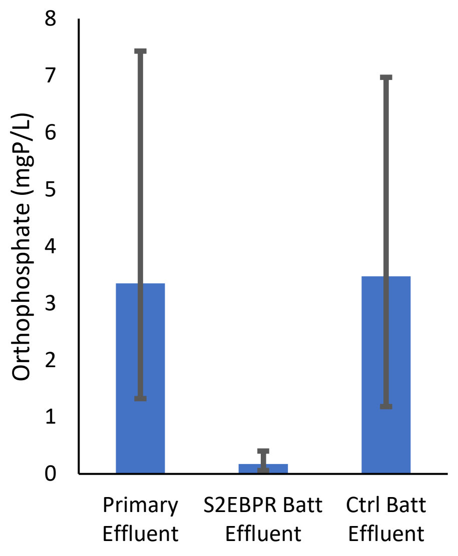
Highlights:

- Scenario IV was the jump start period with the highest external carbon addition
- Scenario V was the optimum scenario with good performance and reduced carbon addition.

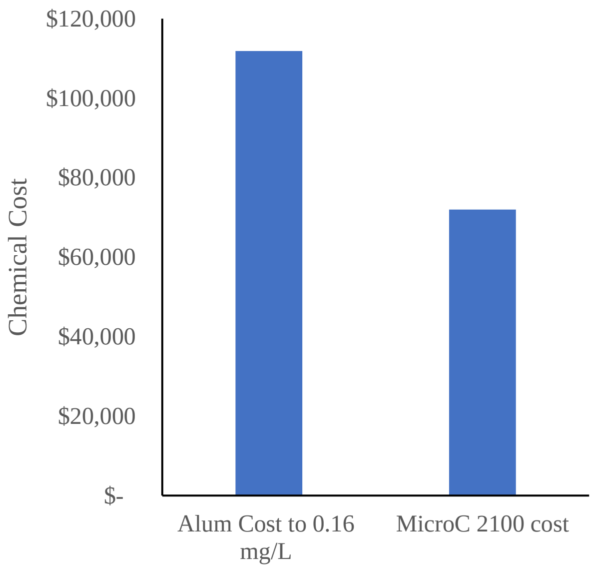
Calumet WRP S2EBPR Pilot Performance – Effluent Averages



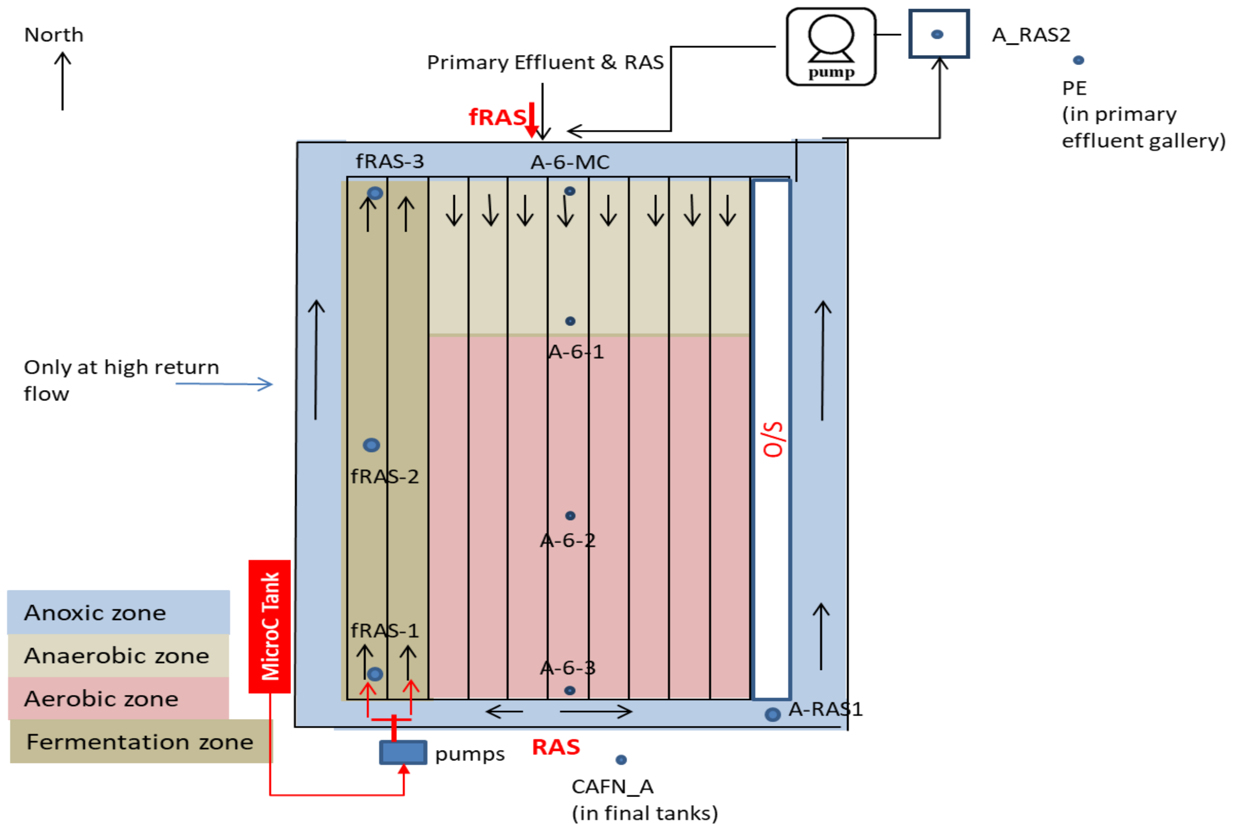
Calumet WRP S2EBPR Demo – Optimum Scenario Performance



* Data from Scenario V (10/7/21 to 11/7/21)

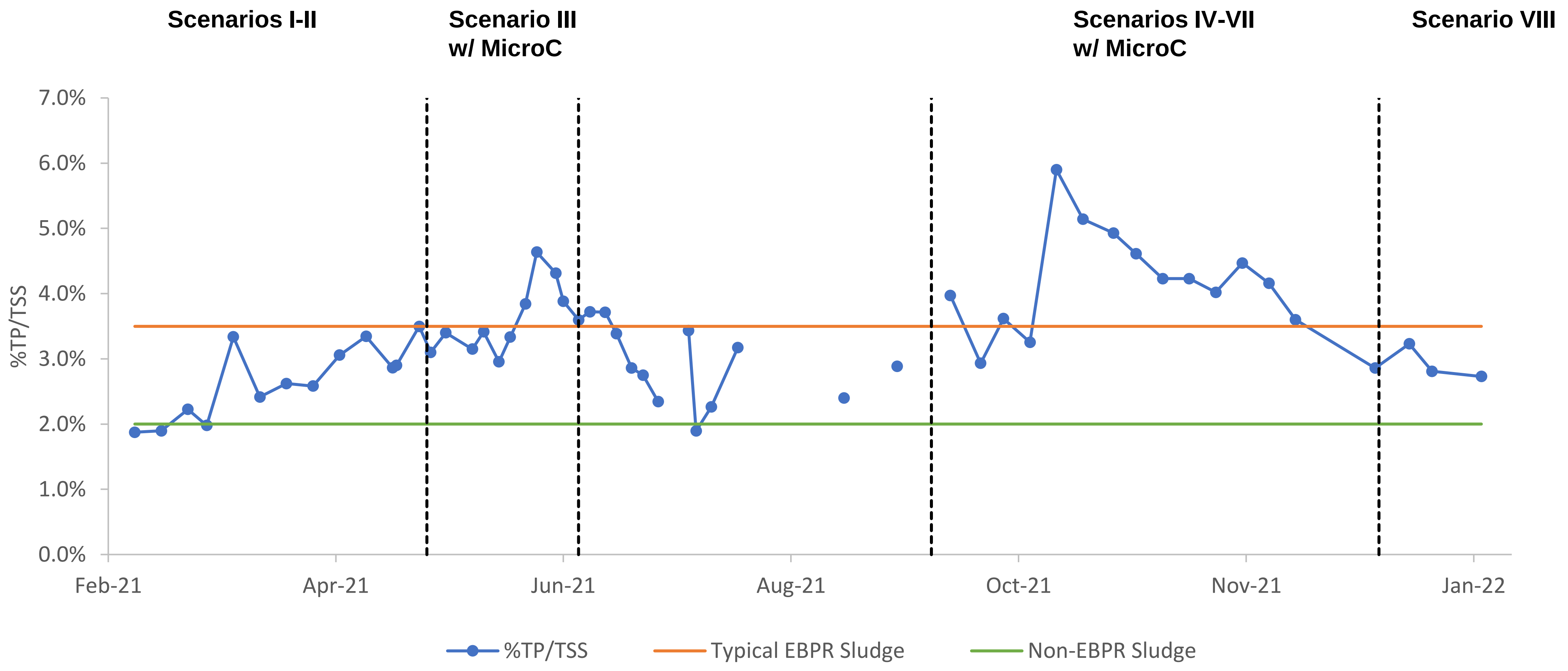


Chemical costs



- S2EBPR battery achieved stable and sustainable performance
- S2EBPR battery well outperformed control battery and had an average orthophosphate of 0.16 mgP/L

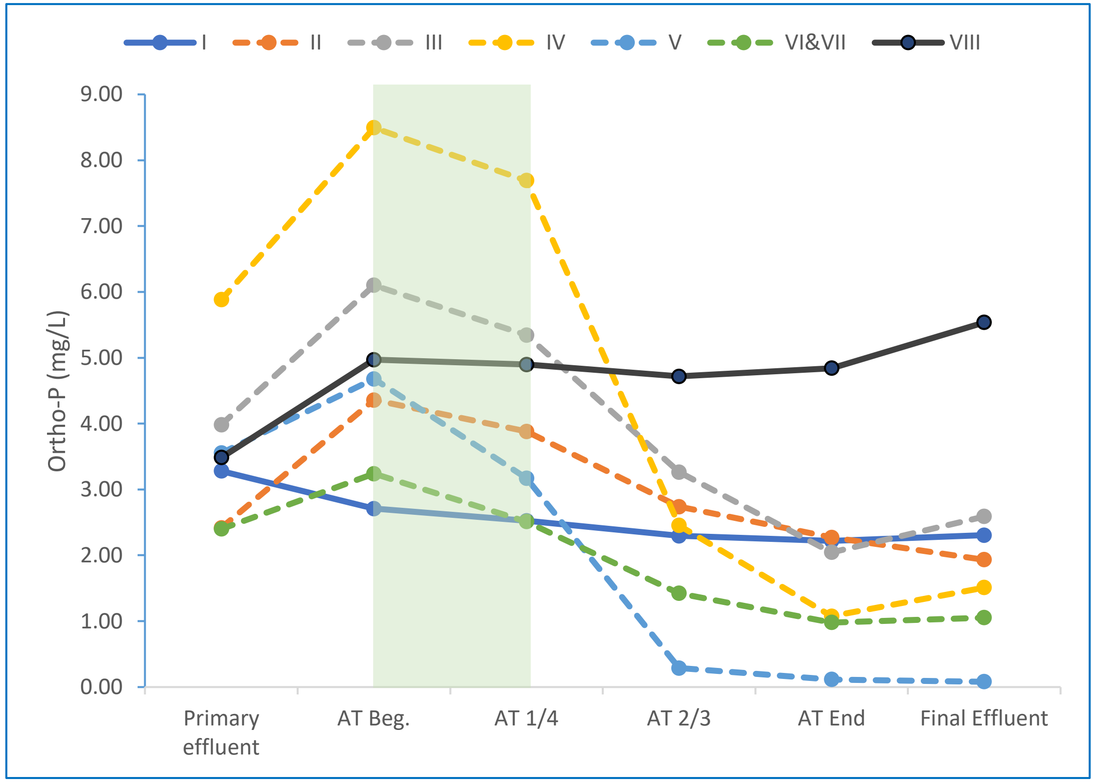
Sludge Phosphorus Content



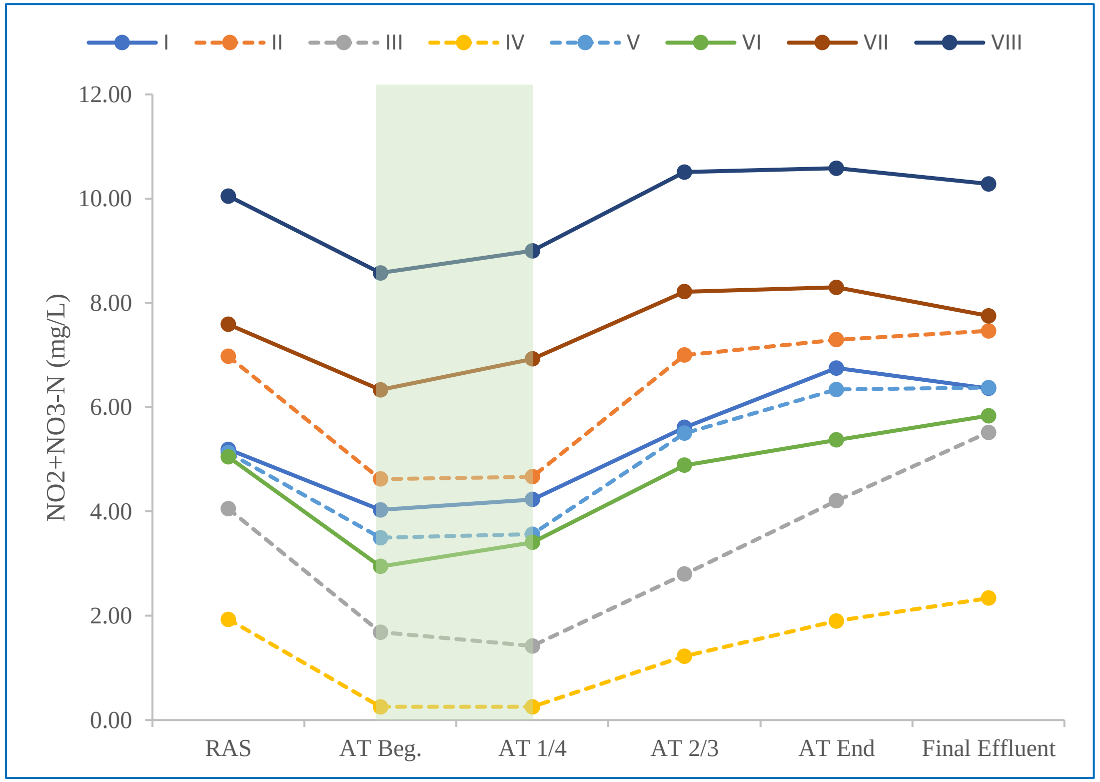
Profile Samplings

Anaerobic PHA storage didn't occur in aeration tank anaerobic zone

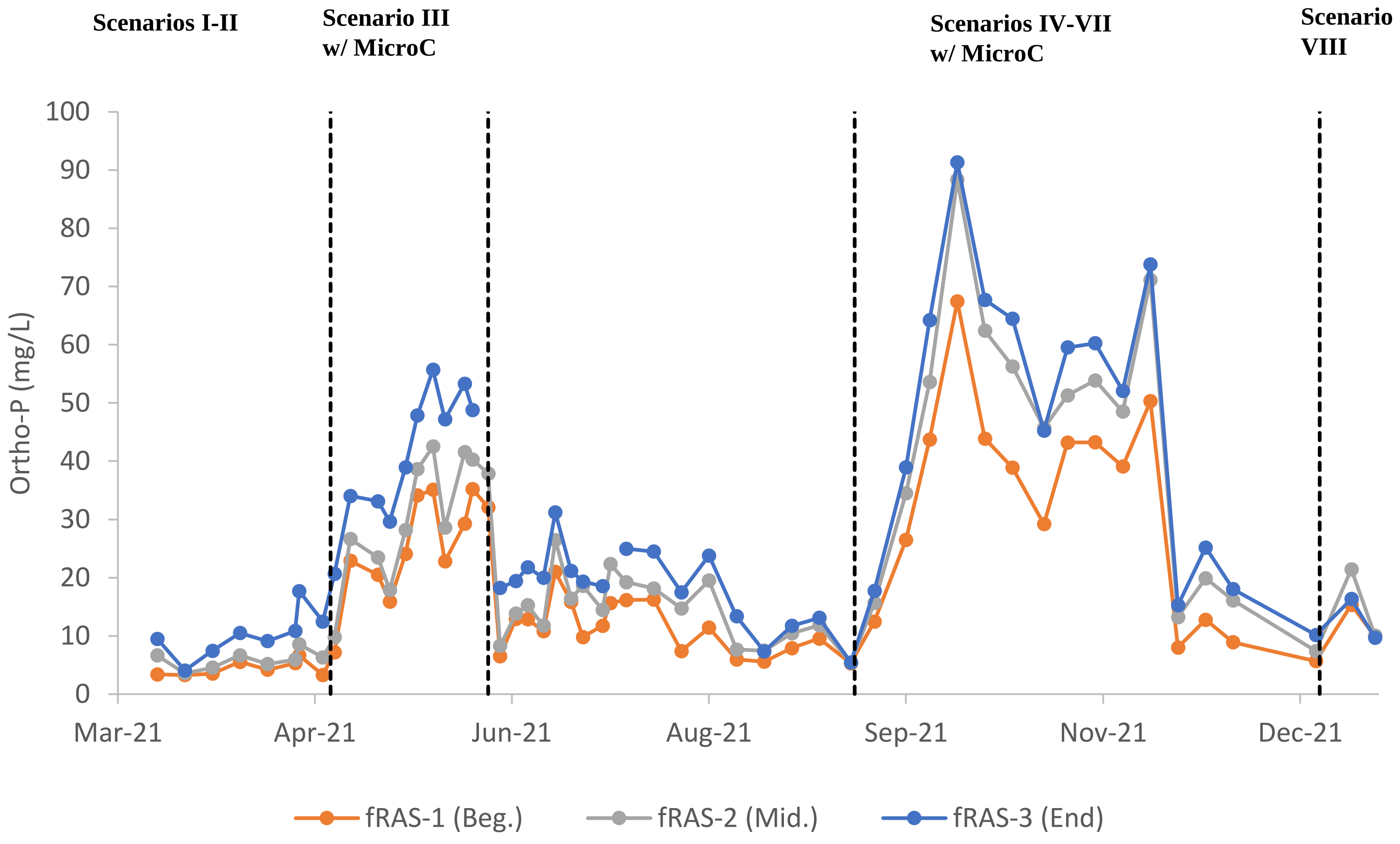
Orthophosphate



NO2+NO3-N

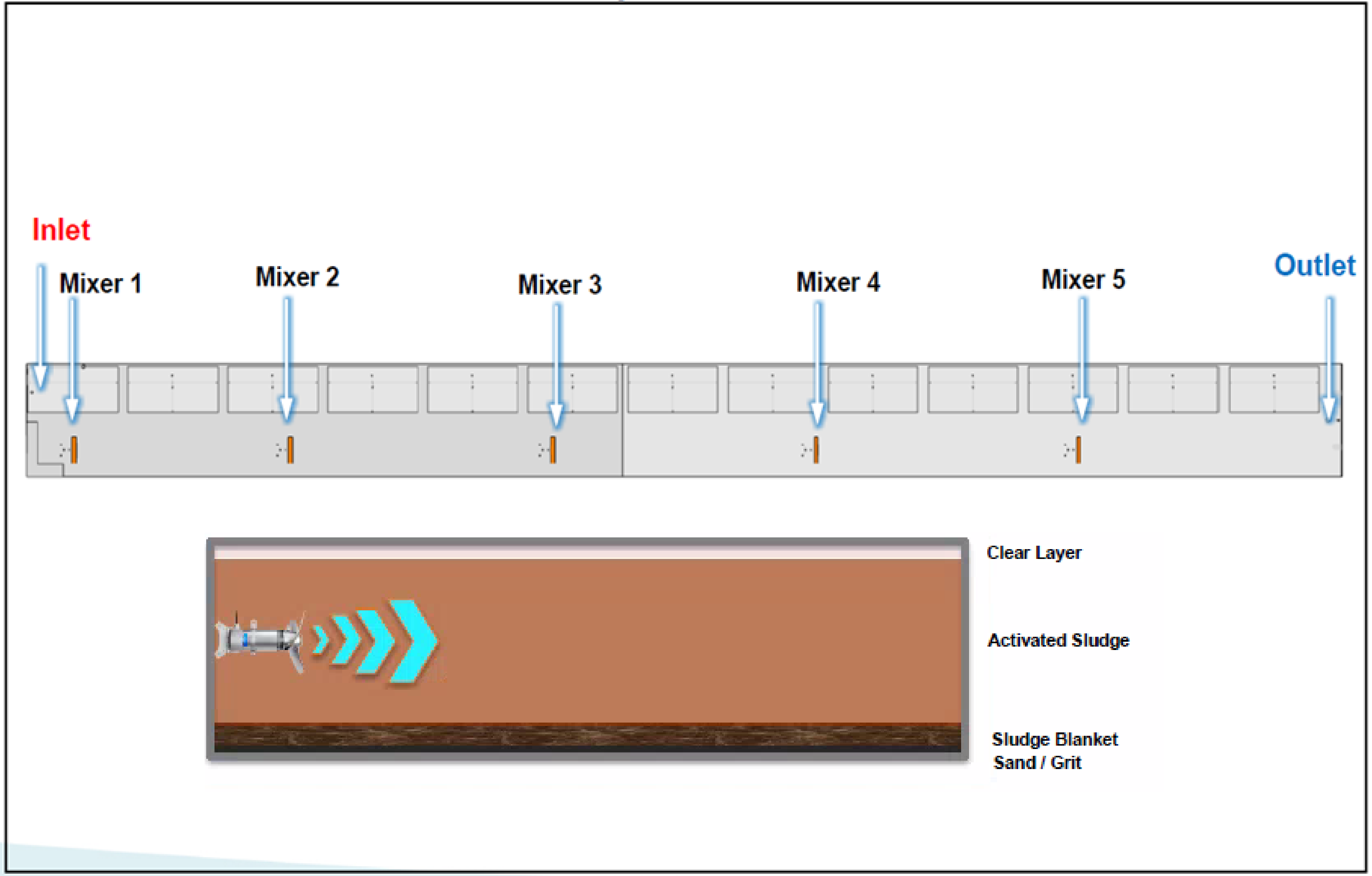


RAS Fermenter Orthophosphate



Mixer numbering

Top View

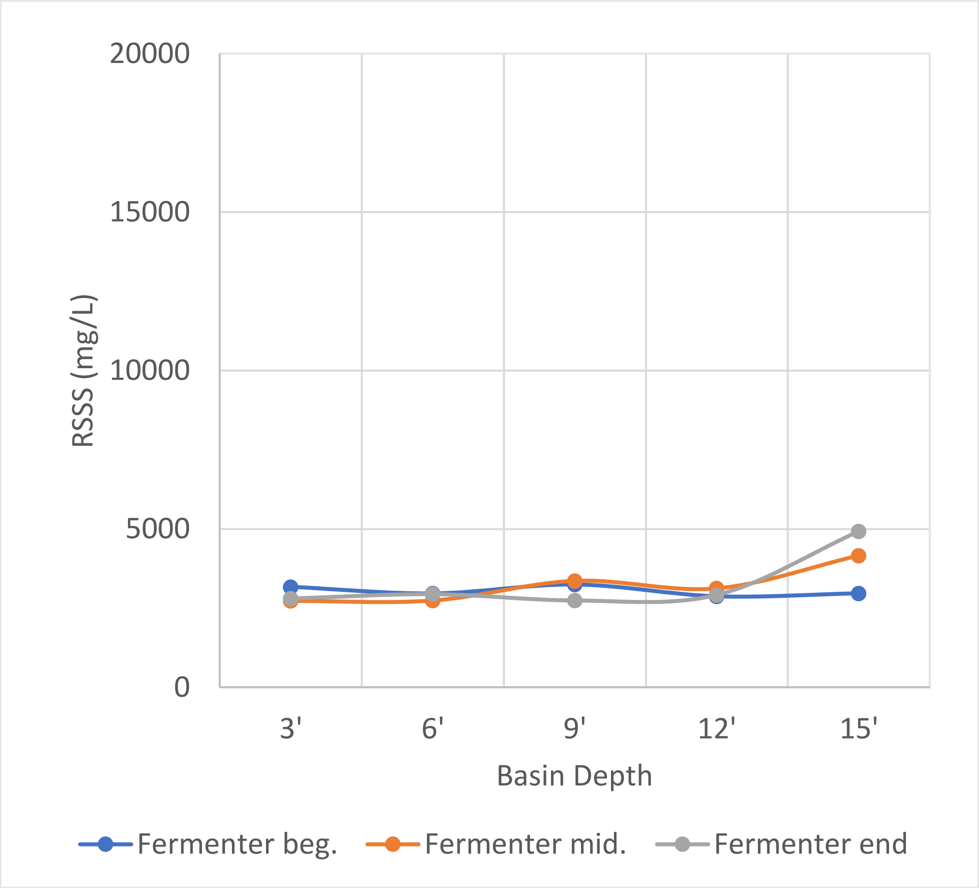


Mixer scenarios:

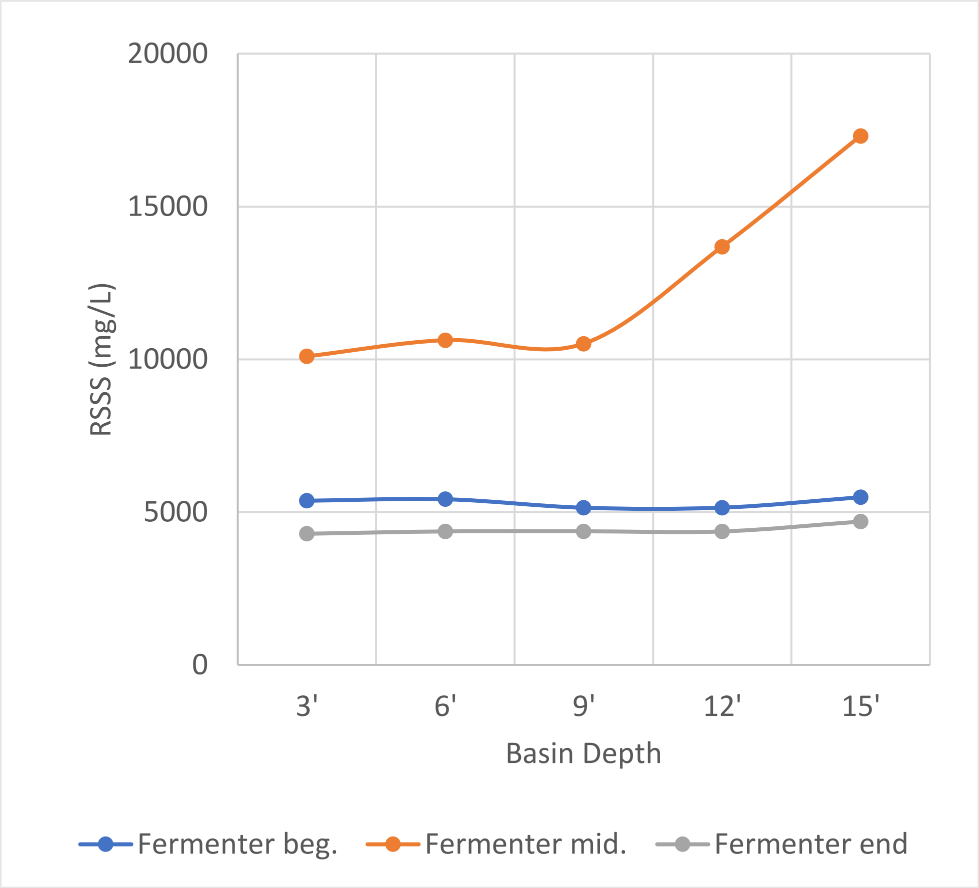
- Mixers 1-4 constant mixing at 16 rpm; Mixer 5 at 23 rpm
  - 0.017 HP/1000 ft3
- Mixers 1&5 constant at 16 rpm; Mixers 2-4 at 4 rpm with daily bumping at 16 rpm
  - 0.006 HP/1000 ft3

RAS Fermenter Suspended Solid Profile

Complete Mixing



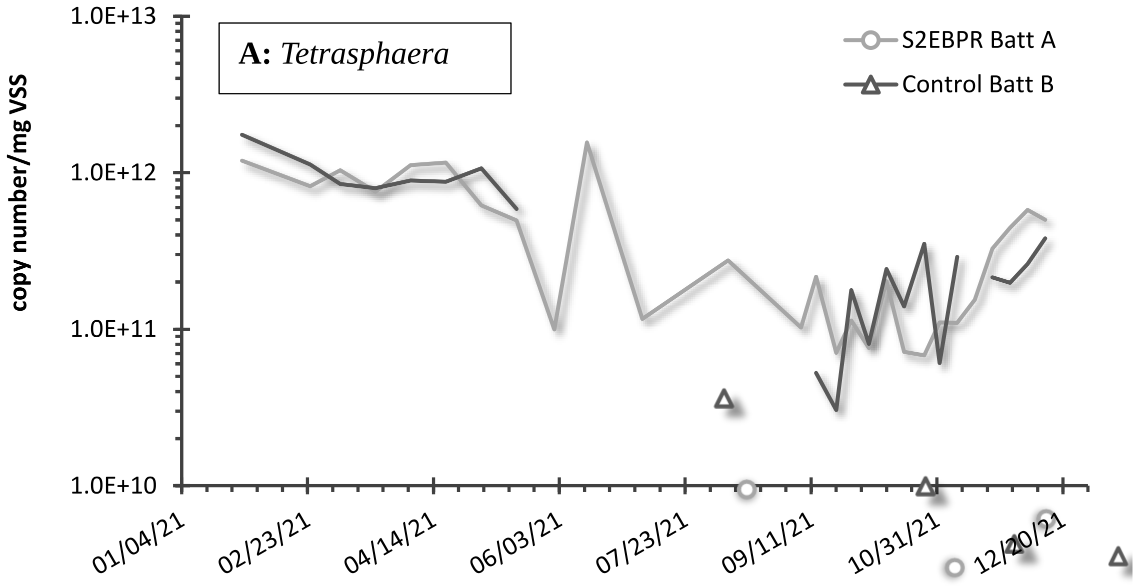
Low Mixing in the Middle

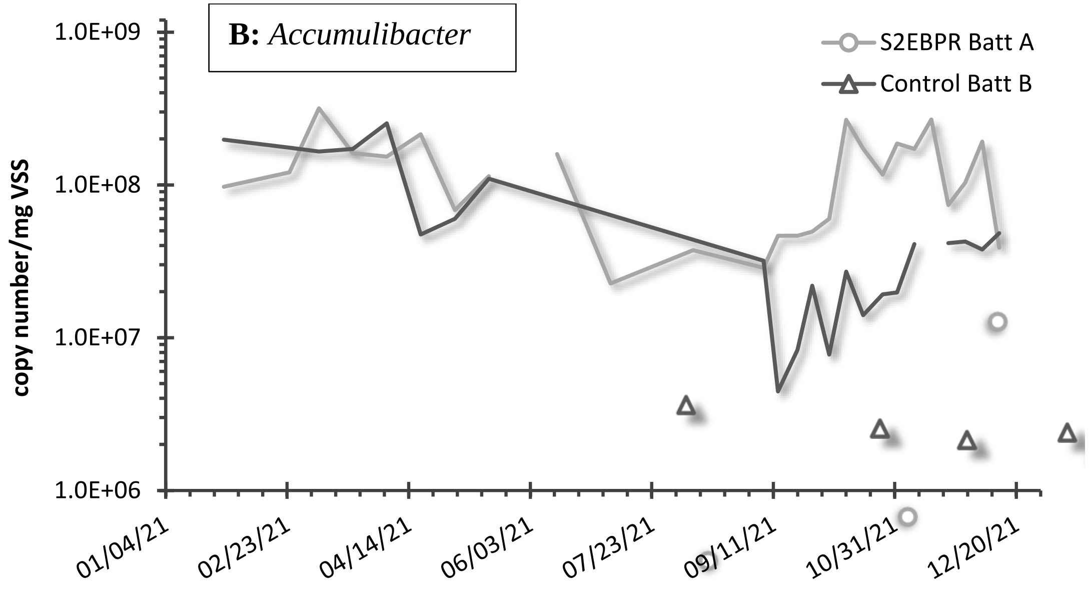


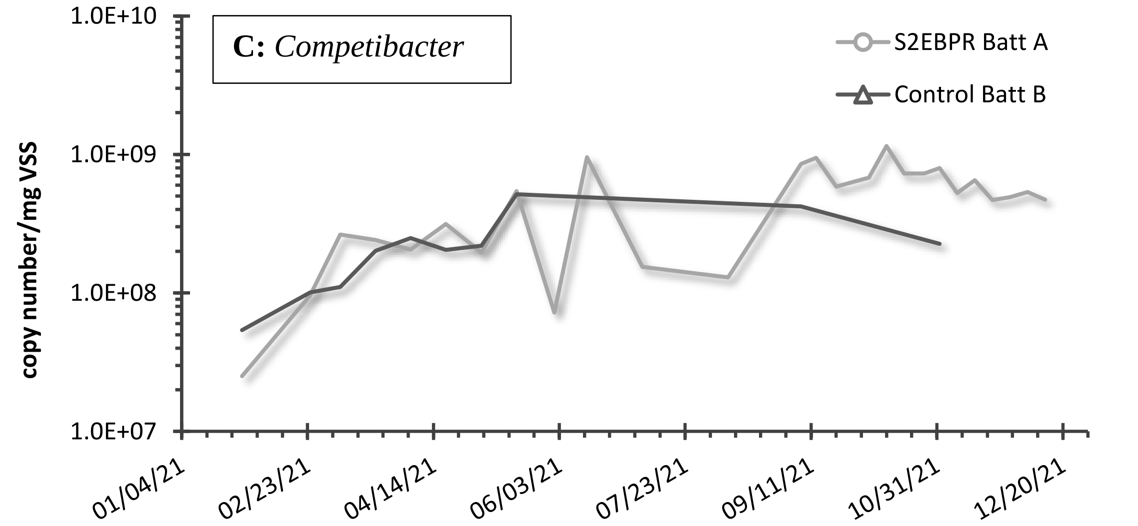
Comparison of Conventional EBPR with S2EBPR

Study Scenarios	2014 Conventional EBPR	2021 S2EBPR Jumpstart	2021 S2EBPR Optimization
Periods	10/13/14-12/25/14	9/7/21-10/7/21	10/8/21-11/7/21
Batt A final effluent ortho-P avg. (mg/L)	1.32	0.41	0.16
Batt A ortho-P removed avg. (mg/L)	2.54	4.38	3.29
Batt A ortho-P removed avg. (lbs/d)	932	1,425	1,579
Batt A ortho-P removal avg. (%)	68	90	95
Dosage avg. (lbs/d)	25,000	24,000	12,500
Primary Effluent BOD:TP	18	20	12
Primary Effluent BOD:TP (with MicroC® 2000 or MicroC® 2100)	25	24	14
Primary Effluent rbCOD:TP (MicroC® 2100)*	ND	12.3	6.0

Characterization of Microbial Community





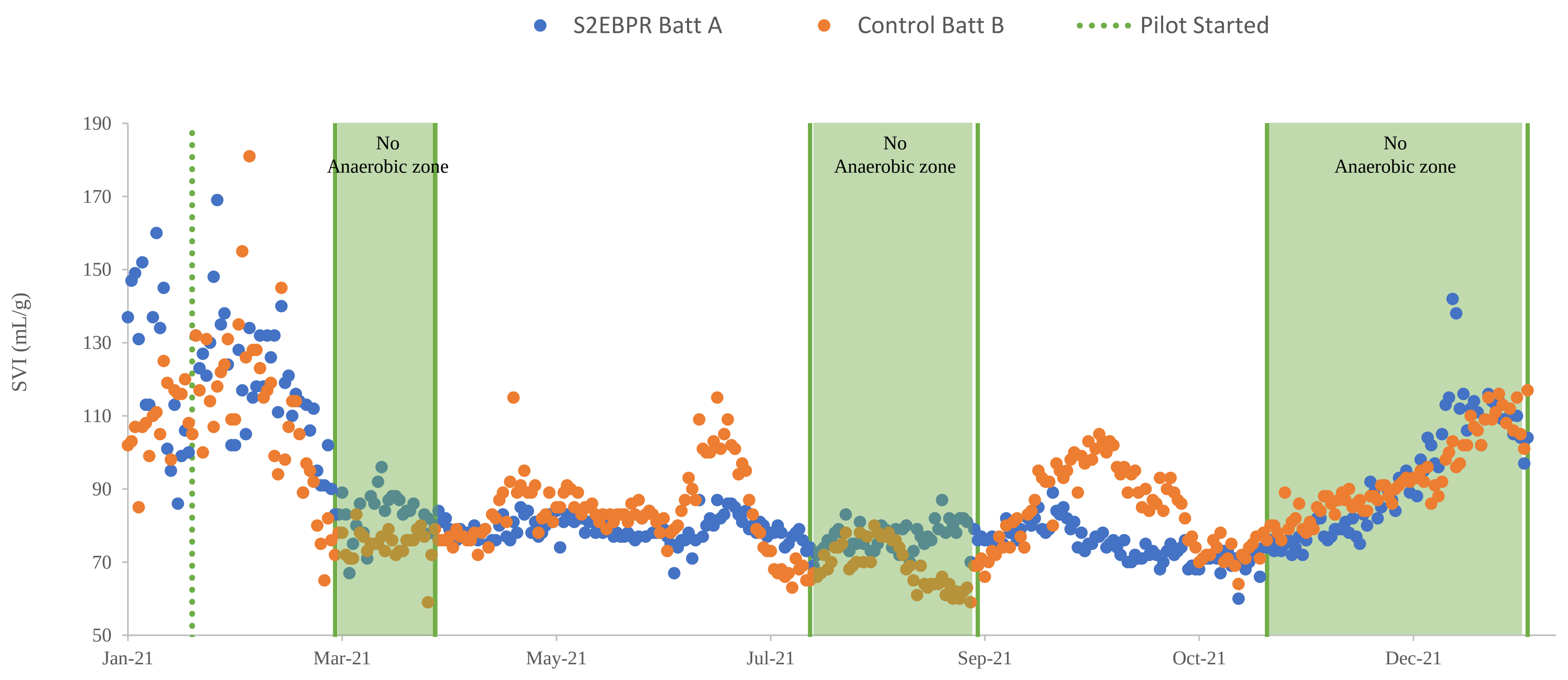


Better P removal performance could due to:

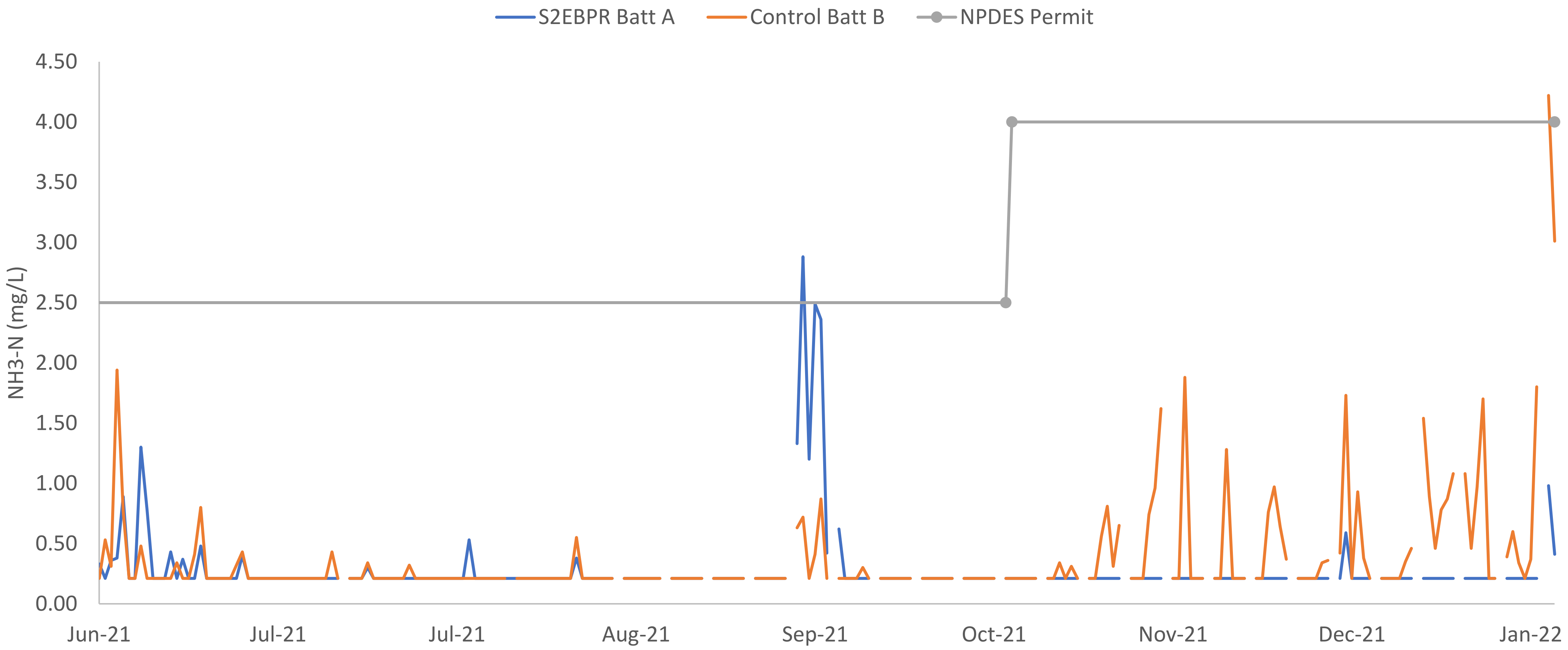
1. Enrichment of *Accumulibacter* from the external carbon addition or the carbon source could have activated *Tetrasphaera* metabolism

2. Higher total PAO abundance

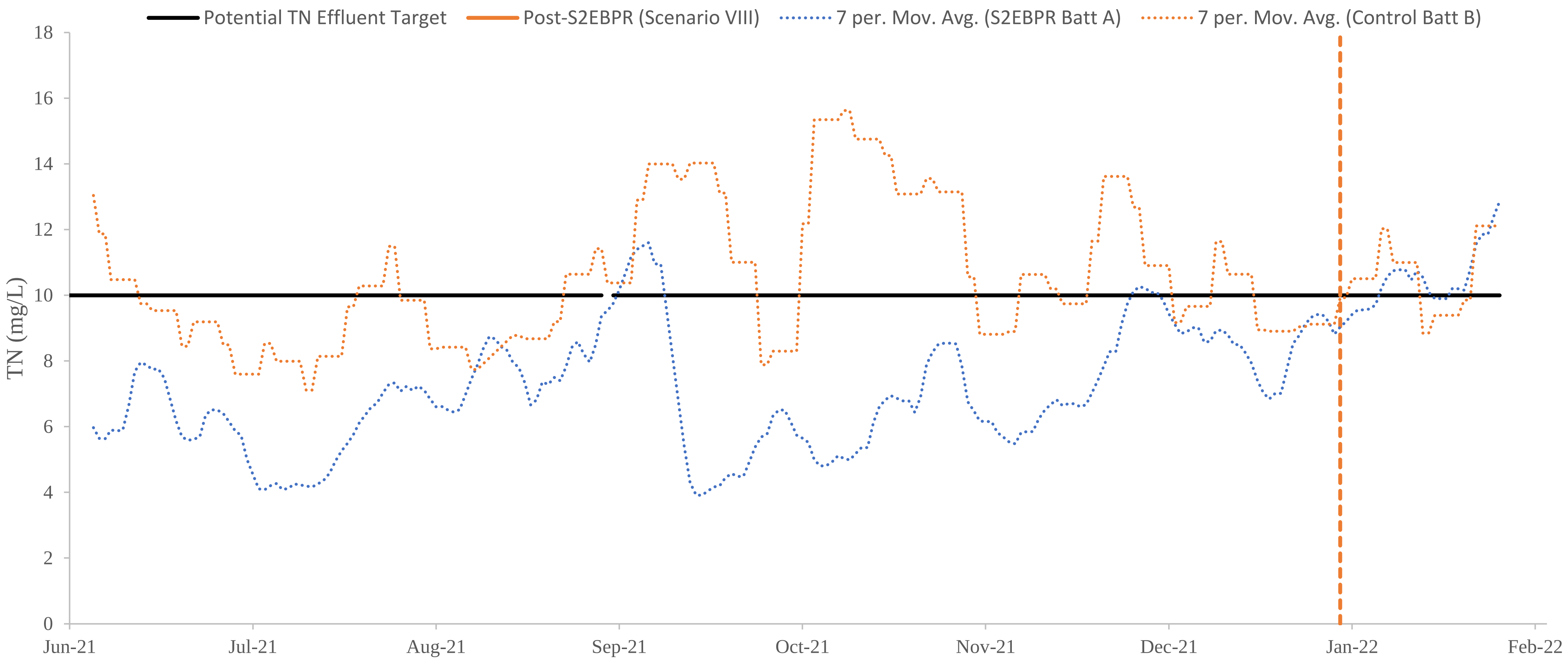
Settleability



Nitrification

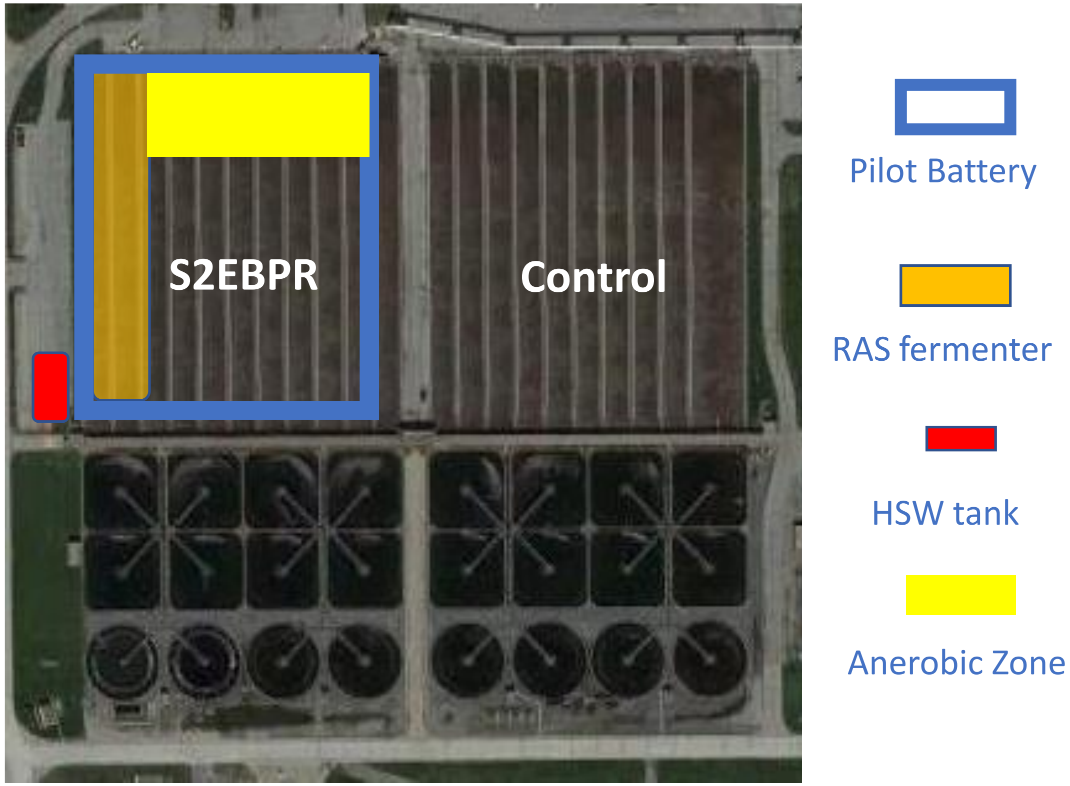


Total Nitrogen Removal

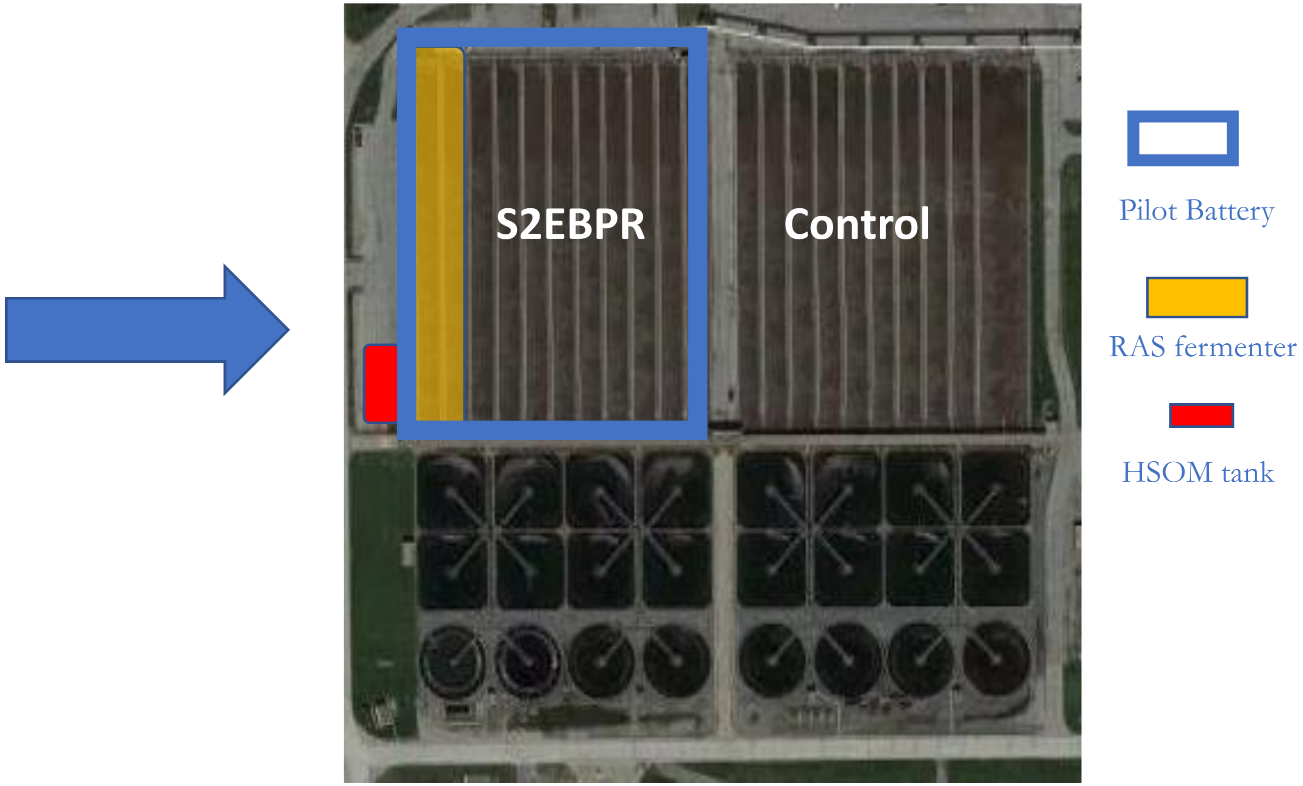


Chem P does not remove TN

S2EBPR Pilot and Recommended Layouts



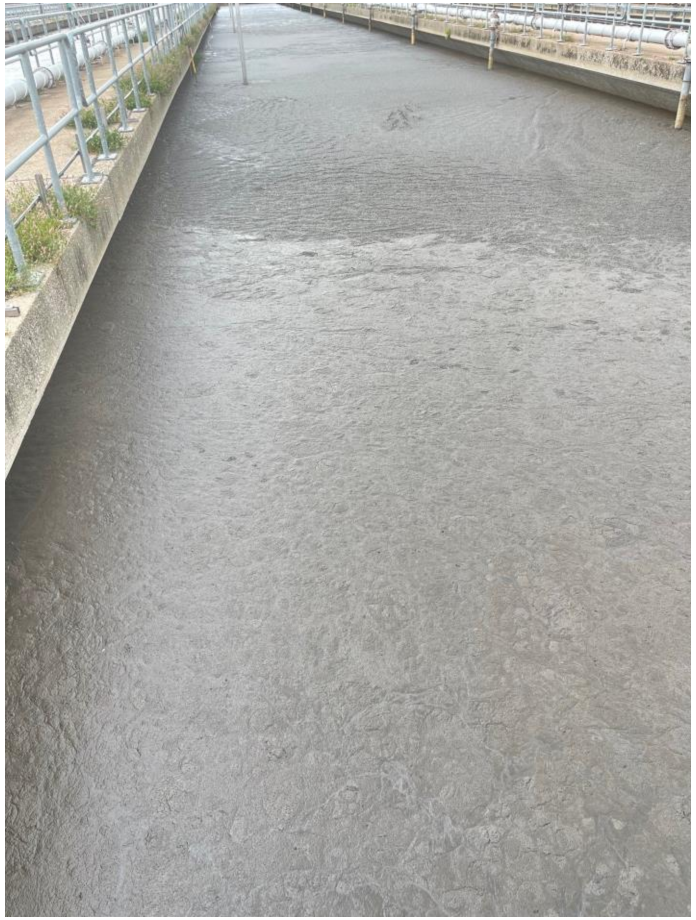
Pilot



Future Design Recommendation

Noted that less nitrate removal due to no anaerobic zone

Operational Issues and Lessons Learned – Fermenter Scum



A thick scum layer developed over the weekend

The scum layer was removed overnight by turning up mixers to higher mixing energy

Operational Issues and Lessons Learned – Final Tank Scum

No Abnormal Filaments in S2EBPR Battery A

Operational Issues and Lessons Learned – Odor and Pumping Issue

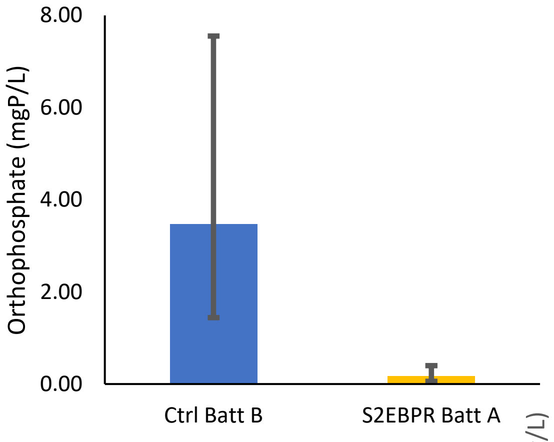
- Odor in the RAS fermenters during daily bumping.
- Difficulty pumping MicroC® 2100 during low temperatures.

Findings – S2EBPR Configuration at Calumet WRP

- RAS divergence: 20 percent
- Fermenter sizing: 10 hours HRT
- Supplemental carbon: at least 12,500 lbs/d COD per each 45 MGD flow
- Mixer operation: low mixing energy with one-hour daily bumping in the middle of fermenter tanks to create sludge stratification and complete mixing at beginning and end of tanks to ensure homogenous sludge in and out
- Anaerobic selectors: <u>not</u> necessary for P removal
- Carbon delivery system: heating for storage tank and heat-traced for piping system
- Final tanks: improved skimming mechanism

Findings – S2EBPR Pilot Achievements

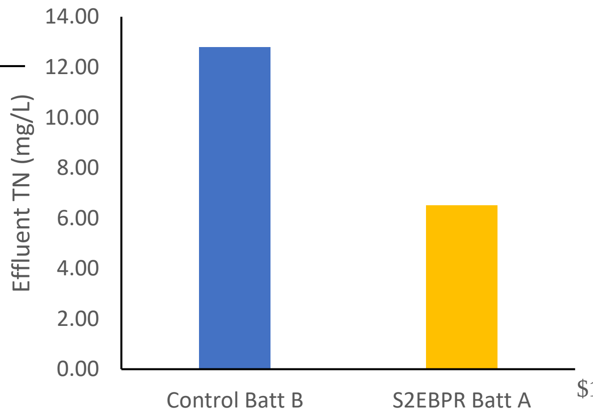
- Low effluent P



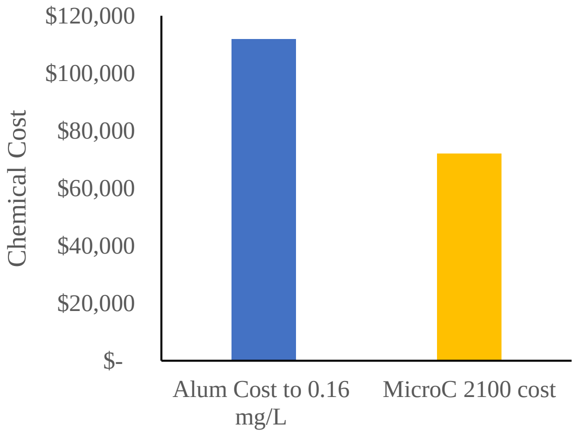
✓ More environmentally friendly

✓ More economical in chemical

- Lower effluent TN



- Lower chemical cost



Next Step – How to Use Pilot Results

- The Phosphorus Task Force met with the Executive Team on September 6, 2022 to determine the path forward for the phosphorus removal evaluation alternatives.
    - Goals are to meet the upcoming lower permit in an environmentally friendly and ecumenical way.
    - Evaluations on different alternatives are ongoing, more to come…

Collaborations and Team Works

- Interdepartmental Phosphorus Task Force biweekly meetings to discuss
  - Pilot performance
  - Progresses of ongoing capital projects
  - Proactive plans

Acknowledgements

- Interdepartmental Phosphorus Task Force
- M&R Staff
  - EM&RD for Field Sampling
  - Analytical Laboratories Division for Chemical Analysis
  - Microbiological Analysis
- M&O Staff
  - TPOs – making the field adjustments
  - Trades – installing monitoring equipment and improving equipment
- Engineering Department
  - Designed and overseed construction of Battery A Pilot

Acknowledgements – EM&RD ERTs

Peter Cashaw; Joe Kadich; Charles Impastato; Bryan Allen; Dushyant Sharma; Eric Gilmore

Metropolitan Water Reclamation District of Greater Chicago

THANK YOU

Cindy Dongqi Qin, PhD

Metropolitan Water Reclamation District of Greater Chicago
qind@mwrd.org