Metropolitan Water Reclamation District of Greater Chicago

Welcome to the October Edition of the 2021 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- All attendees' audio lines have been muted to minimize background noise.
- A question and answer session will follow the presentation.
- Please use the "Chat" feature to ask a question via text to "All Panelists."
- 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. LEON DOWNING, P.E.
PRINCIPAL PROCESS ENGINEER/INNOVATION LEADER
BLACK & VEATCH

Dr. Leon Downing is a Principal Process Engineer and Innovation Leader with Black & Veatch. Dr. Downing provides technology leadership in support of Black & Veatch process engineering and applied research projects globally. Dr. Downing has spent the last 15 years working with process and operational changes focused on energy efficiency, nutrient removal, and resource recovery. He is currently serving as the Principal Investigator for Water Research Project 4975, which focuses on developing practical considerations for fermentative enhanced biological phosphorus removal. Dr. Downing is also a co-Principal Investigator on Water Research Project 5083, where low energy biological nutrient removal processes are being investigated. Between these two research projects, design guidelines for the next generation of biological nutrient removal facilities will be developed for the industry.

Best Practices in Kinetic Rate Testing and Data Interpretation to Measure EBPR Health – A Water Research Foundation Study

Leon Downing, PhD, PE

Patrick Dunlap, PE

Yueyun Tse, PhD, PE

April Gu, PhD, PE

This project was funded by The Water Research Foundation.

Agenda/Presentation

- EBPR health
- Rate testing to inform EBPR optimization
- RAS fermentation case study

WRF 4975 is focused on practical considerations for sidestream enhanced biological phosphorus removal

- 21 participating utilities globally
- $1.3 M research project value
- Identified as one of the top 10 Water Innovations for
- Principal Investigator: Leon Downing, BV
- Co-PI: April Gu, University of Cornell
- Goals:
  - Develop design criteria for the processes
  - Identify operational tools for EBPR
  - Recommend process modeling guidelines

WATER ONLINE

WATER INNOVATIONS CURRENT ISSUE

2020

Sidestream Enhanced Biological Phosphorus Removal Made Easier

Some excellent progress has been made in recent years on sidestream enhanced biologic phosphorus removal, but a current project promises to advance the practice even further.

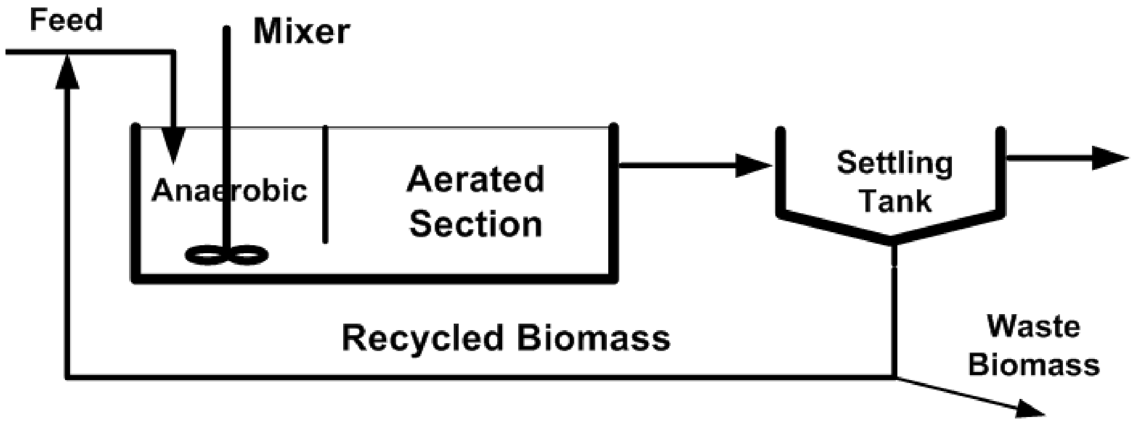

EBPR Health

How do we better understand EBPR limitations?

“In biology, nothing is clear…Nature is anything but simple.”
Richard Preston, Author of The Hot Zone

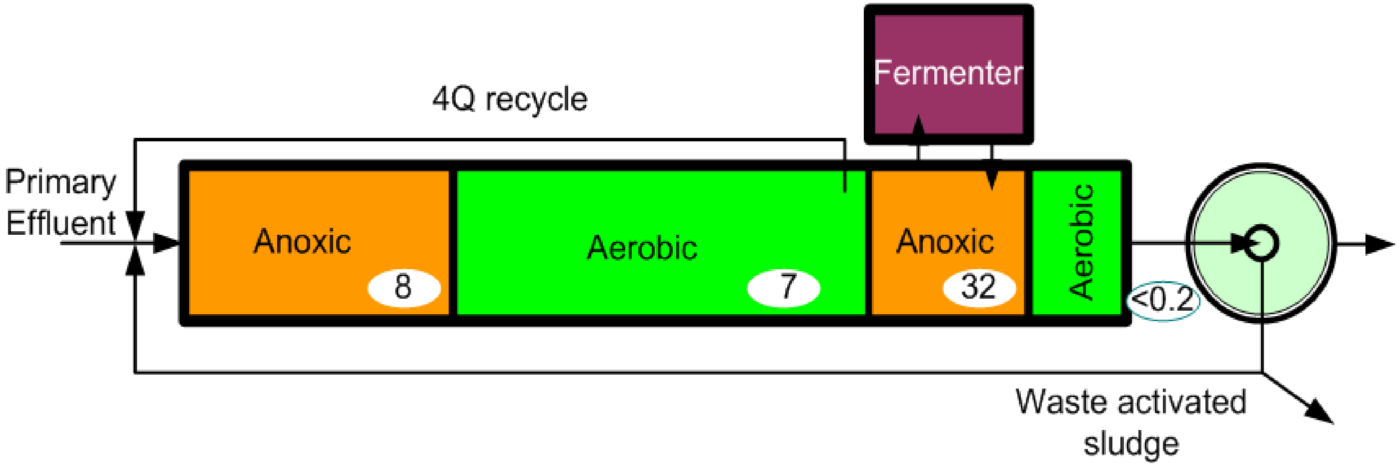
Evolution of Enhanced Biological Phosphorus Removal (EBPR)

- A two-step process of phosphorus release and uptake under alternating anaerobic and aerobic conditions.
- Phosphorus is released in the anaerobic zone to 25 to 40 mg/L, taken up in the aeration basin to as low as 0.05 mg/L soluble P.



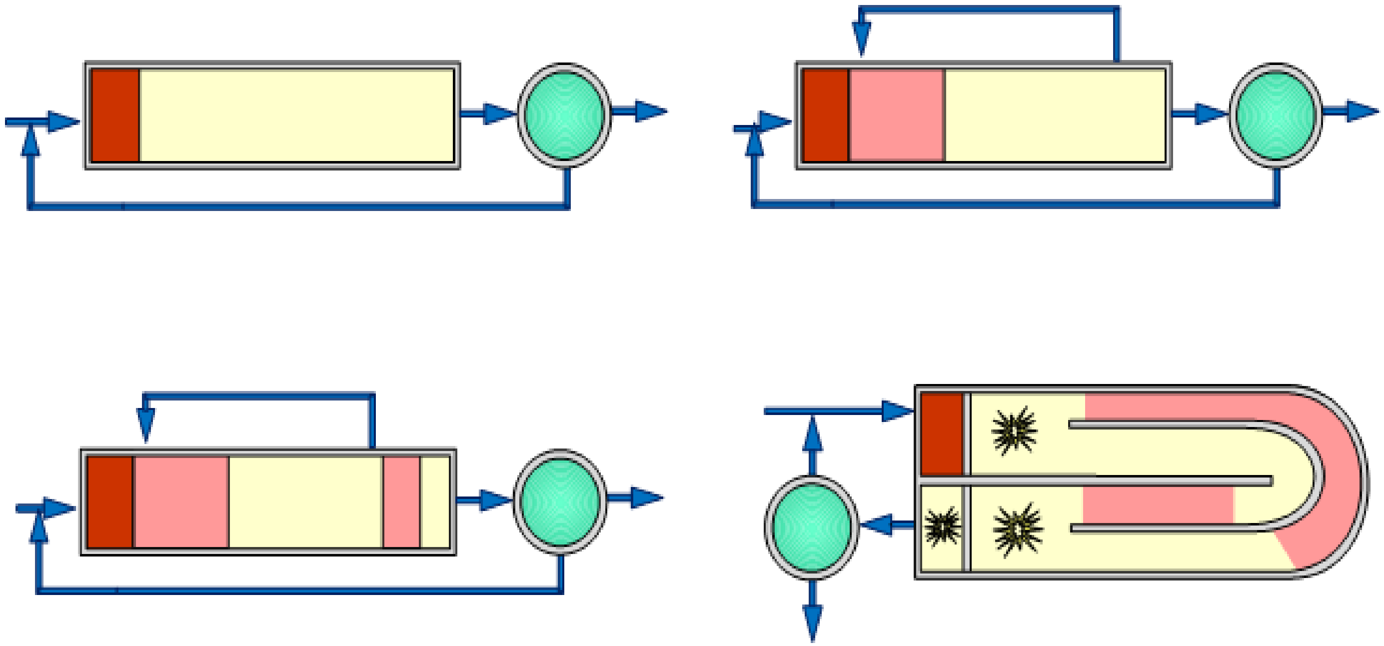
Initial pilot testing by James Barnard indicated the importance of influent VFA and influent selector

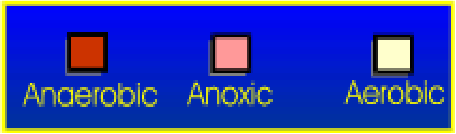
- Note orthophosphates profile through plant with high release in 2nd Anoxic zone
- Performance could not be replicated in laboratory
- Barnard postulated that organisms (PAO) should pass through anaerobic phase with low ORP and P release, which triggered EBPR
- Suggested Phoredox process by adding anaerobic zone up front



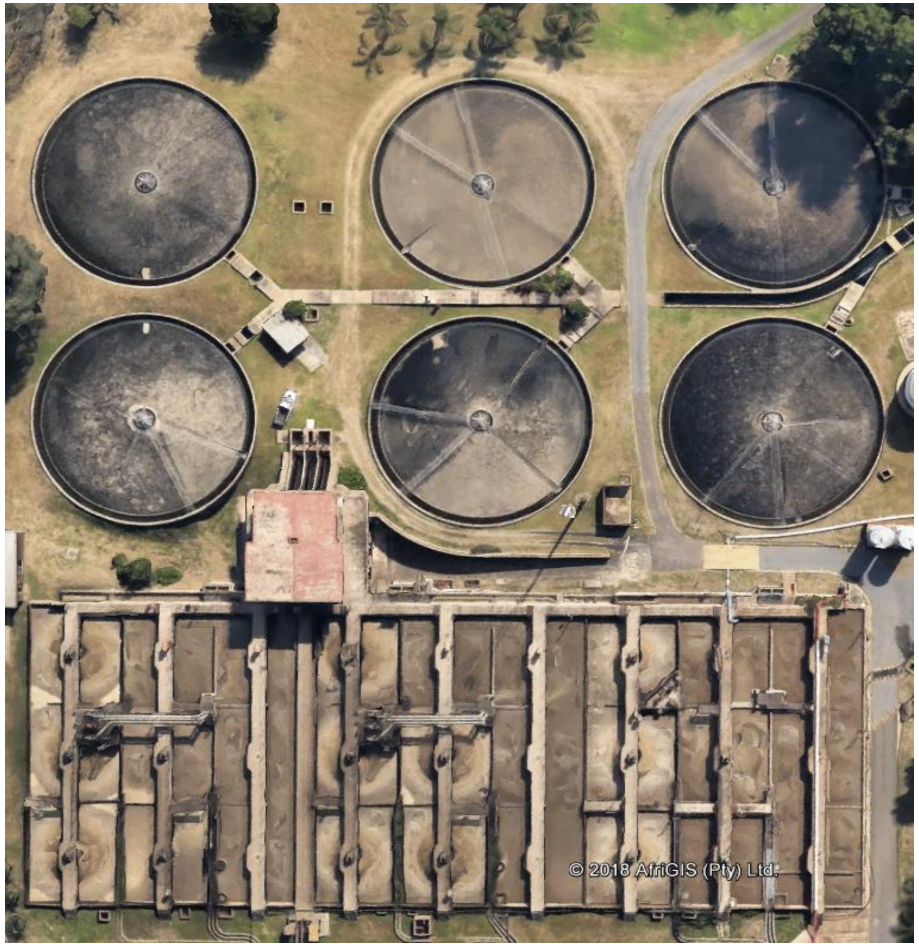
Barnard 100 m^3/d pilot 1972

Proposed flow schematics were developed based on original thinking

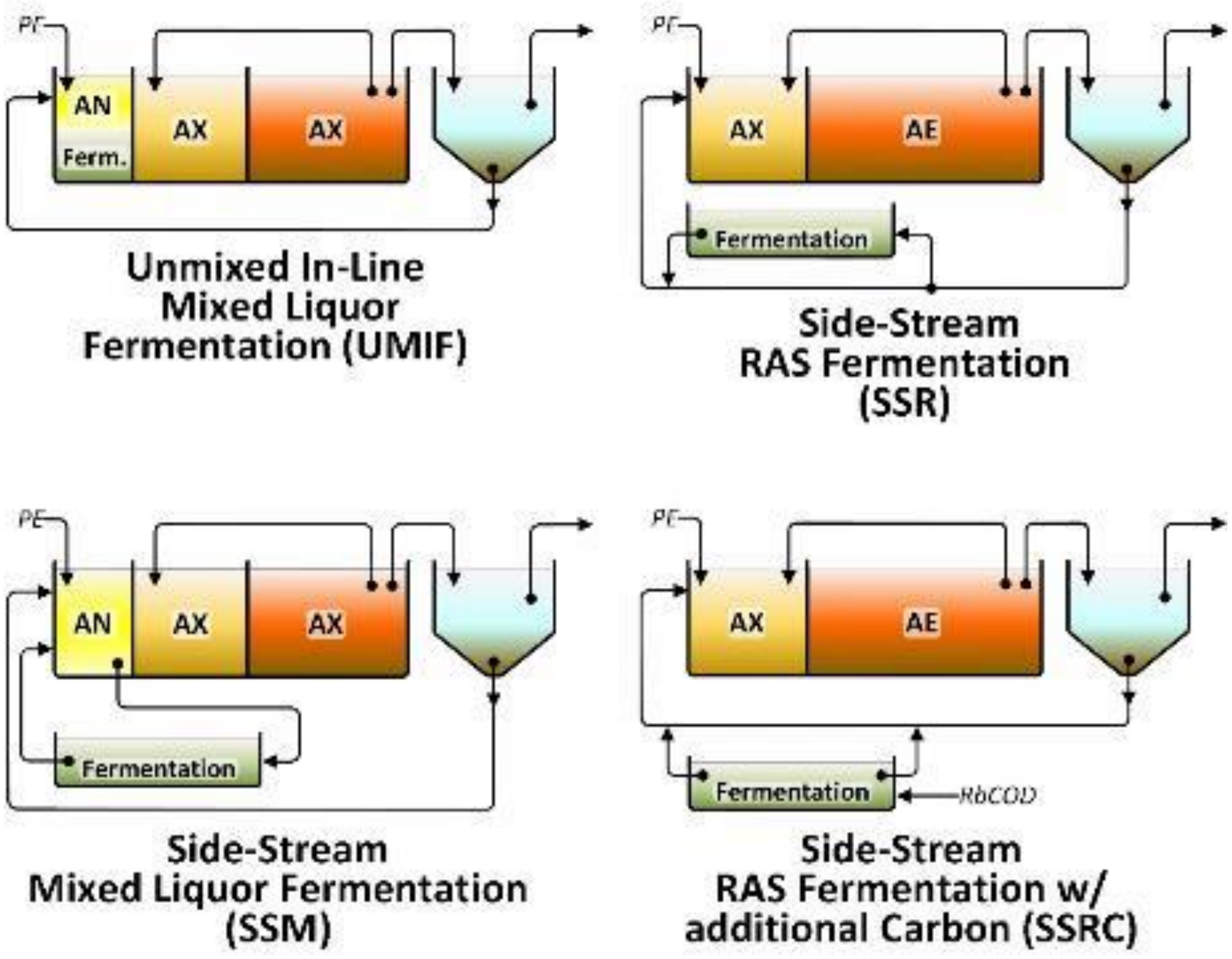




Construction Started October 1974
Flow Diagrams Published July 1975 as Phoredox
Renamed AO, A2O, April 1976



These were followed by others such as UCT, JHB & Westbank

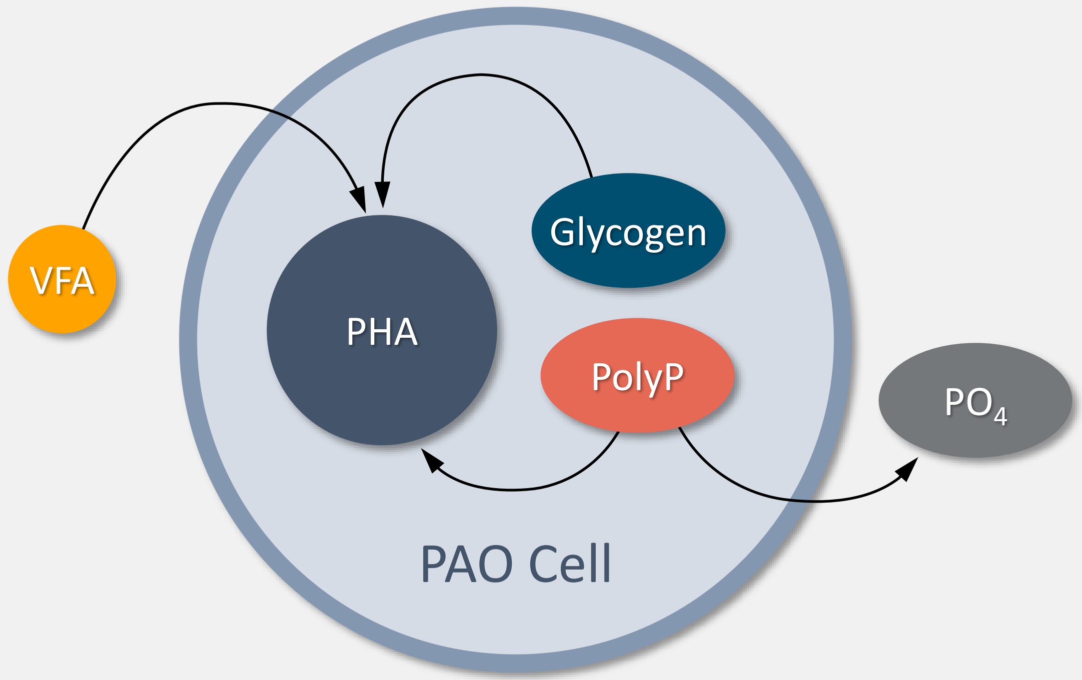


S2EBPR generates carbon from biomass to drive EBPR

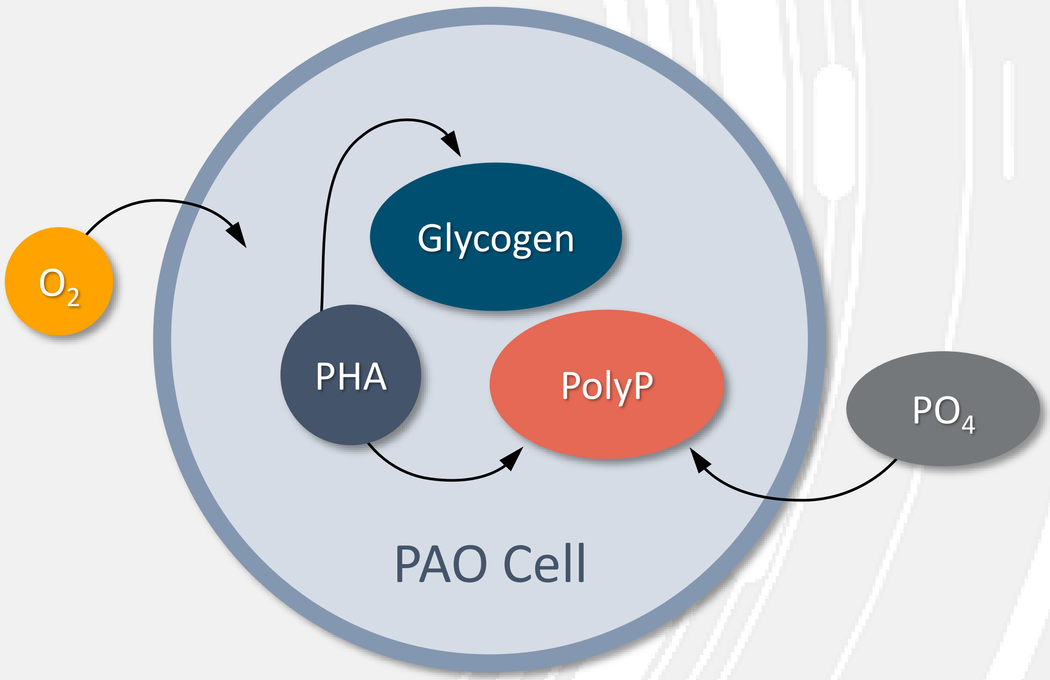
- Deep ORP selects for a more diverse PAO ecology, which provides access to a wider range of COD fractions

Phosphate Accumulating Organisms (PAOS) are Focused on BOD Storage in Anaerobic Conditions

Anaerobic Conditions

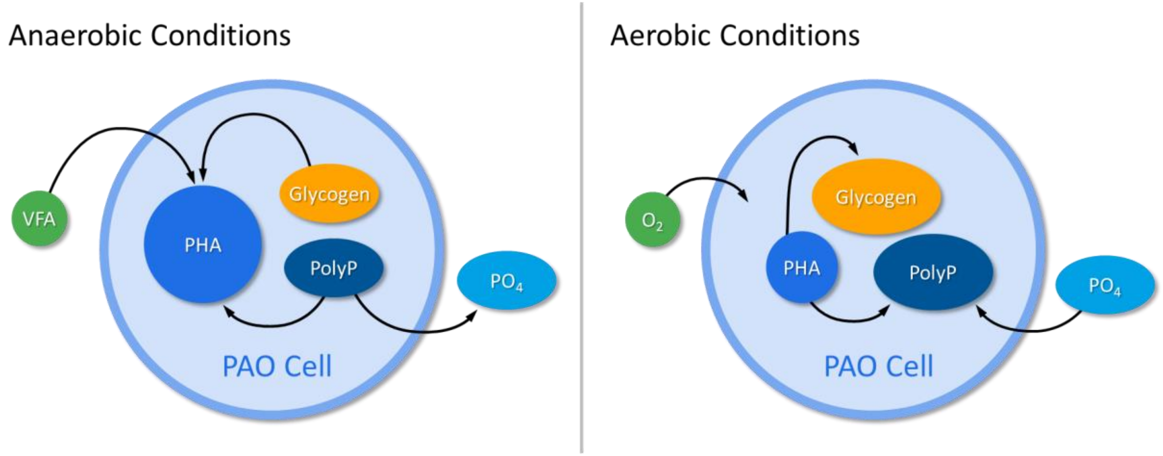


Aerobic Conditions



How do we better understand what is limiting PAO function?

Optimizing EBPR requires more than effluent monitoring



- Several different mechanisms for PAOs
- Effluent performance can suffer days after event that creates increased effluent
- Simple rate testing can be used for monitoring PAO health
- Modeling can be used to inform optimization efforts

Rate Testing to Understand PAO Health

Can we use rate testing to better understand PAO function?

- Are we achieving PHA storage and phosphorus release?
- Is phosphorus uptake and PHA breakdown occurring?
- How much extra PHA is available at the end of aeration?

Release and uptake rate testing can be used as indicators of PAO population and activity

Sample from end of aeration basin, spike with acetate, measure phosphorus, then aerate to measure uptake rate

Indicator of PAO activity

Before Test

- **Activated Sludge** — Mixed Liquor from end of Aerobic Zone
- **Pre-conditioning of Activated Sludge***
  - Residual C
  - Residual N
  - Residual P
- **Anaerobic Condition** — N_2 sparging to DO< 0.1 mg/L

During Test

- **Carbon Dosing***
  - C type
  - Initial C concentration
- **Sampling**
  - Start immediately after carbon dosing
  - Every 5 min for the first 2-3 samples
  - Every 15 min until the end

pH: Adjust to 7 and monitor (shouldn't change significantly)

DO: monitored and maintained to < 0.1 mg/L

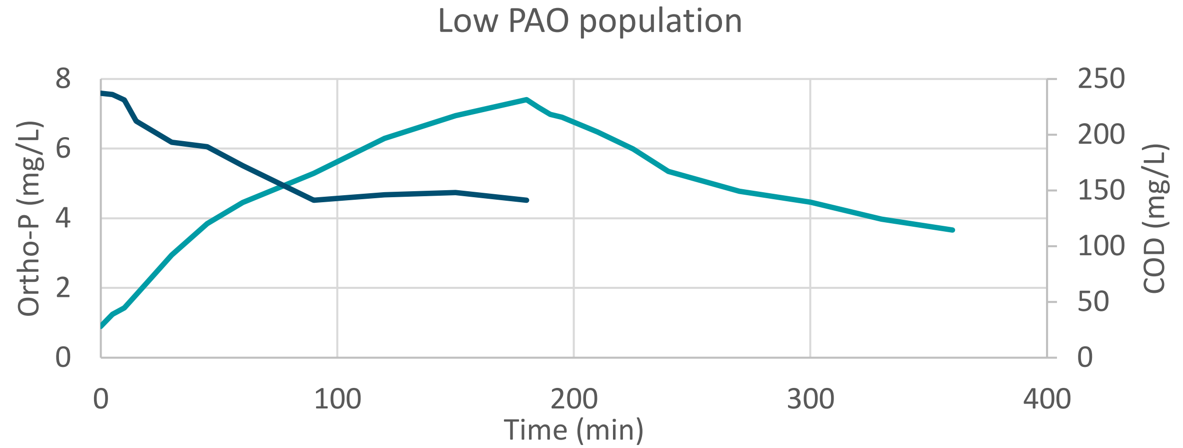
T: Bring to room temperature and monitor

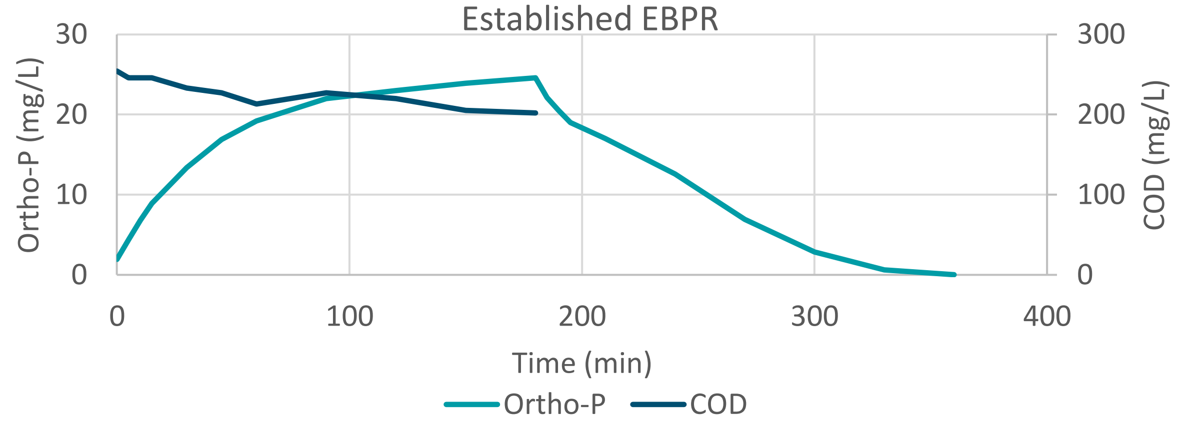
Duration: 30min-1h until C uptake ceases

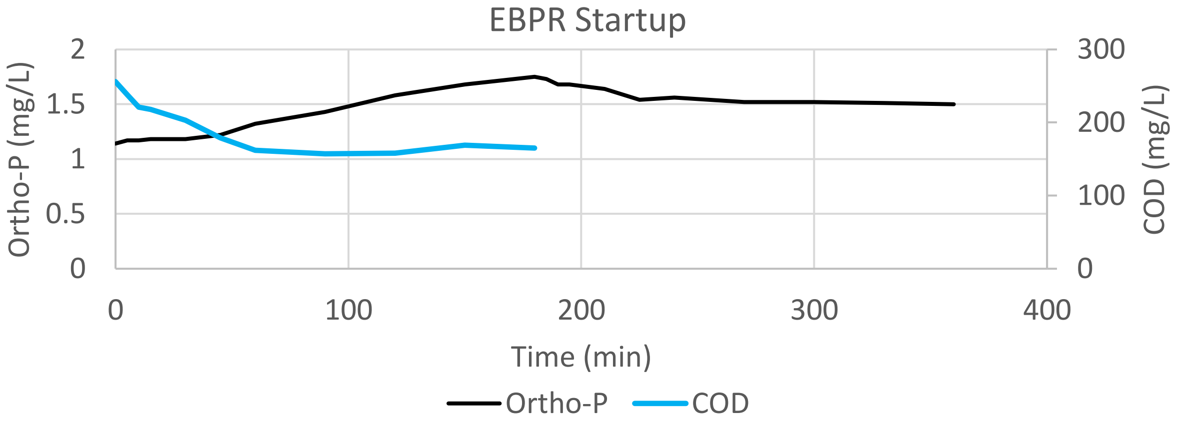
After Test

- **Chemical Analysis**
  - Primary:
    - Ortho-P, C source (acetate etc.), NO2, NO3 in all samples
    - TSS &VSS at beginning/end
  - Optional:
    - Glycogen, PHAs

* Site-Specific Considerations







Developed for WRF 4975 Design of S2EBPR

Residual phosphorus uptake rate can be implemented to understand PHA reservoir for phosphorus uptake

Sample from end of aeration basin, spike with phosphorus, measure uptake rate

Indicator of how much PHA is stored

Before Test

Activated Sludge — Mixed Liquor from end of Aerobic Zone

Pre-conditioning of Activated Sludge* —
- Residual C
- Residual N
- Residual P

Aerobic Condition — O_2 sparging to DO > 2.0 mg/L

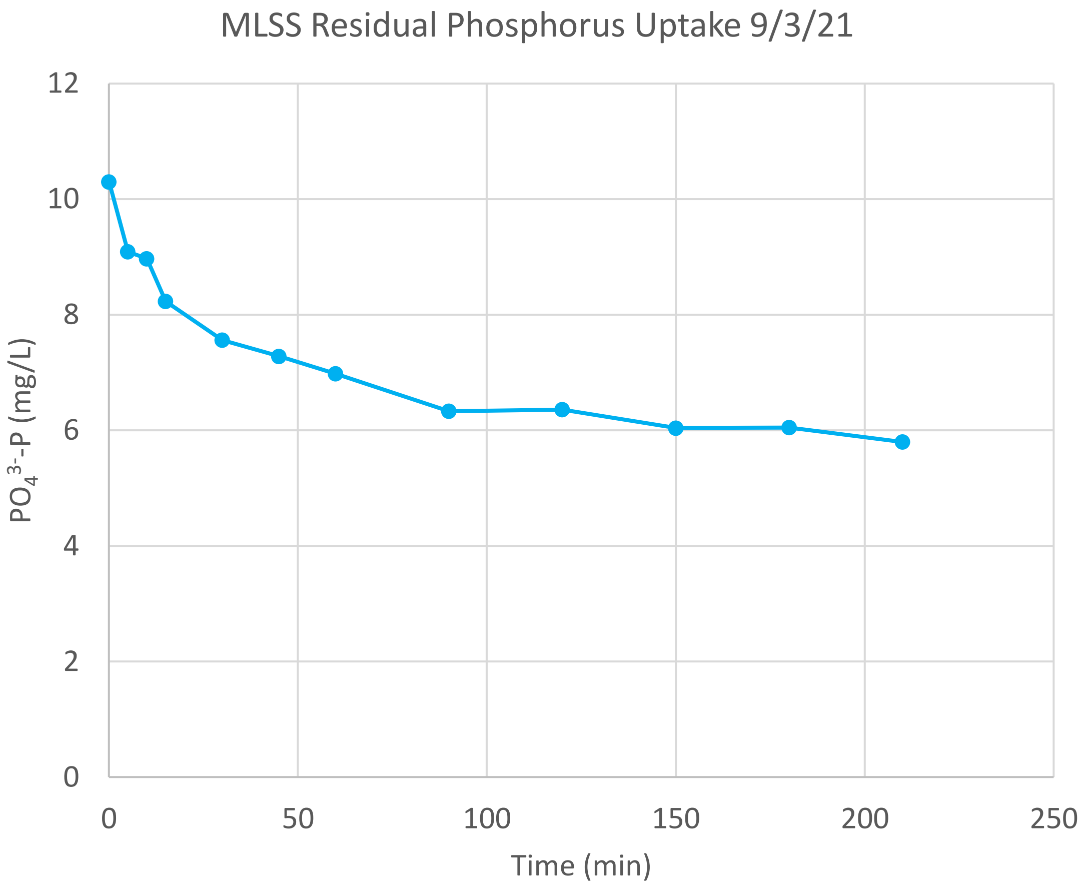
During Test

Phosphorus Dosing —
- Spike with orthophosphate
- Initial P > 10 mg/L

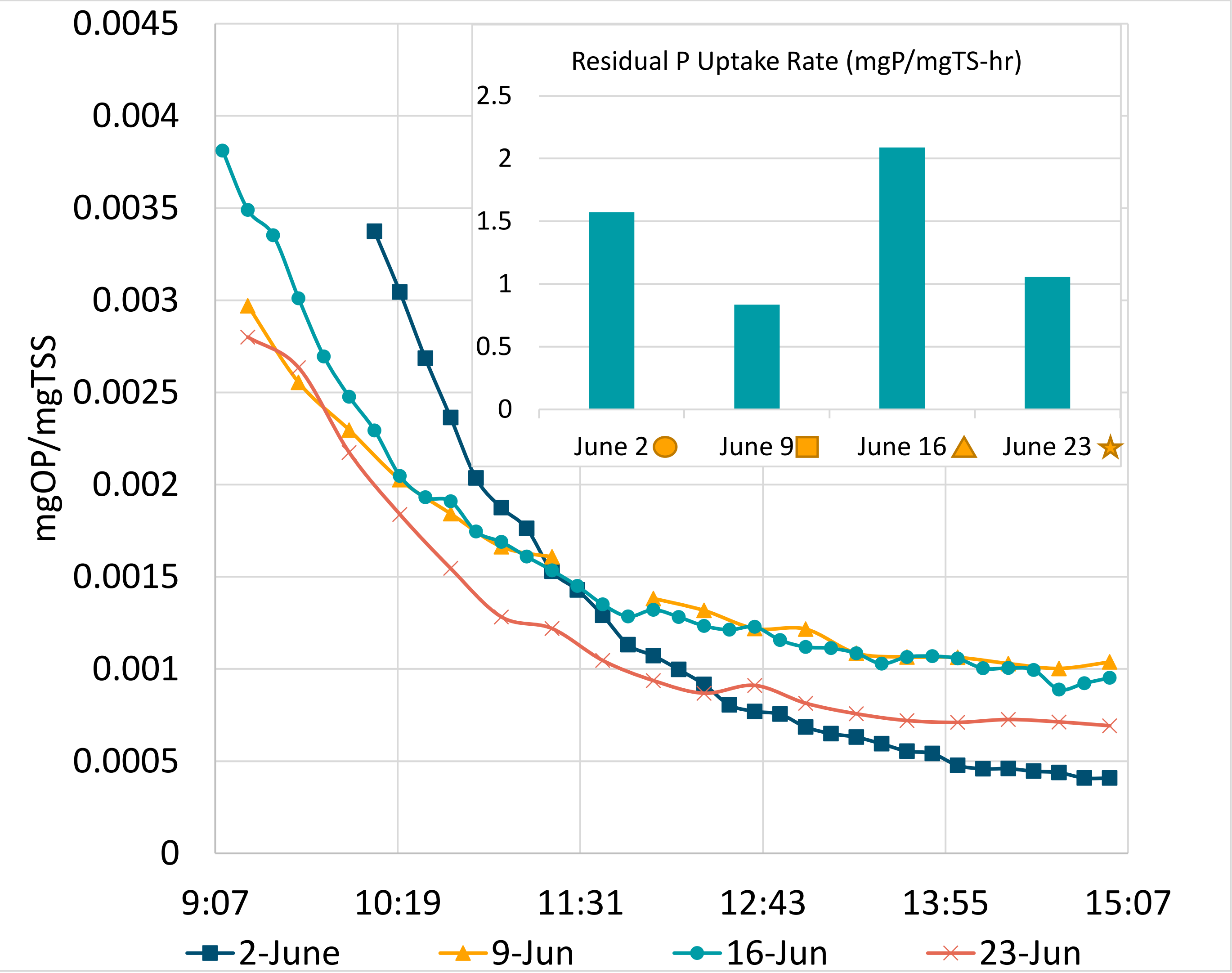
Sampling —
- Start immediately after phosphorus dosing
- Every 5 min for the first 2-3 samples
- Every 15 min until the end

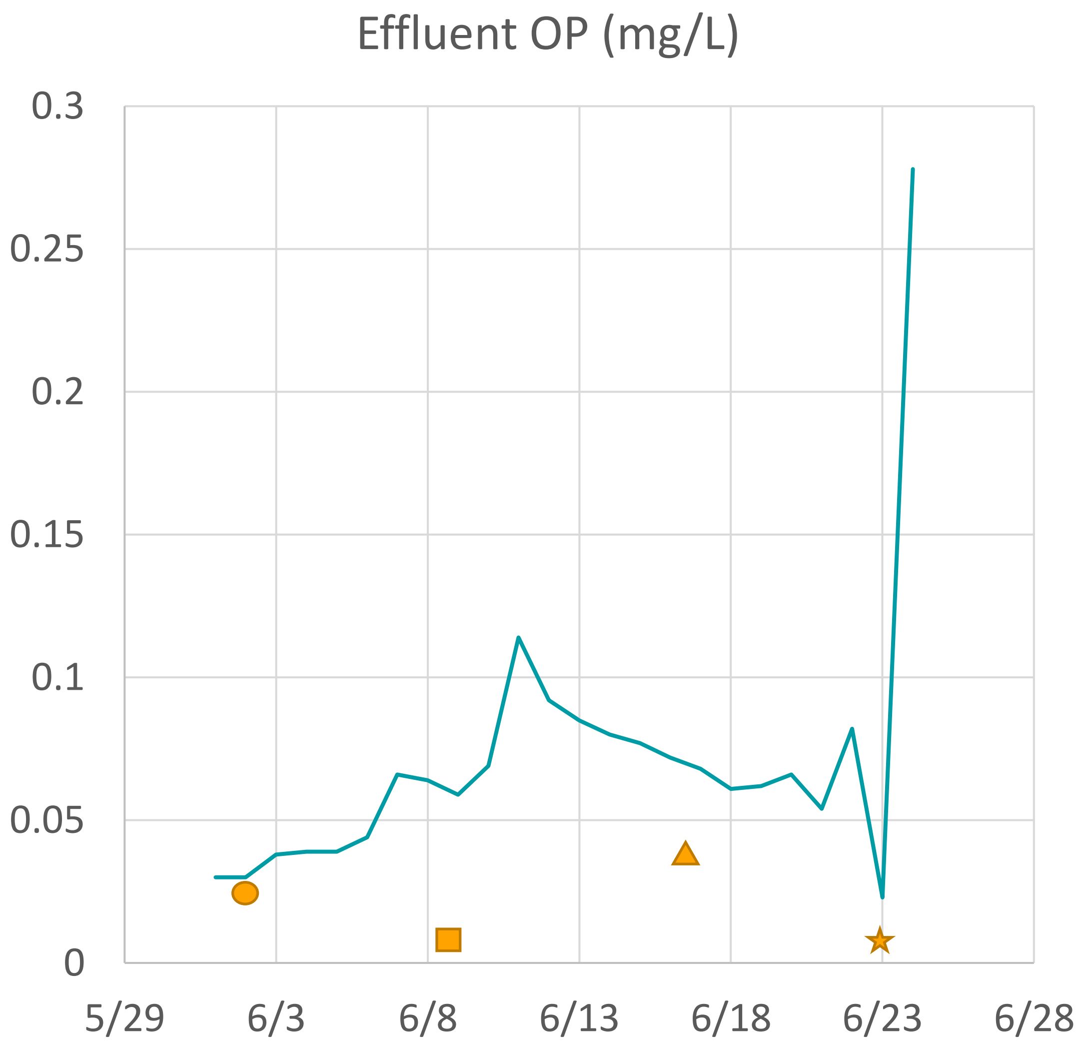
After Test

Chemical Analysis — Primary:
- Ortho-P, NO2, NO3 in all samples
- TSS &VSS at beginning/end



Residual phosphorus uptake rate testing can be an indicator of PHA limitation





Fermentation rate can help identify the availability of carbon in the RAS of the system

Sample from RAS prior to selector zones

Fermentation rate testing can identify P release and carbon release from RAS

Before Test

Activated Sludge * — Fermenter Influent (e.g. RAS or RAS with other Carbon sources)

Anaerobic Condition * — Achieve and maintain DO< 0.1 mg/L throughout the test

During Test

Mixing * — Low energy constant mixing/ Intermittent mixing

Sampling
- Every 6 h for the first 24 hrs
- Reduce frequency to 12-24 hours if test run exceeds 24 hrs.

pH: monitor

DO: monitored and maintained to < 0.1 mg/L

T: Bring to room temperature and monitor

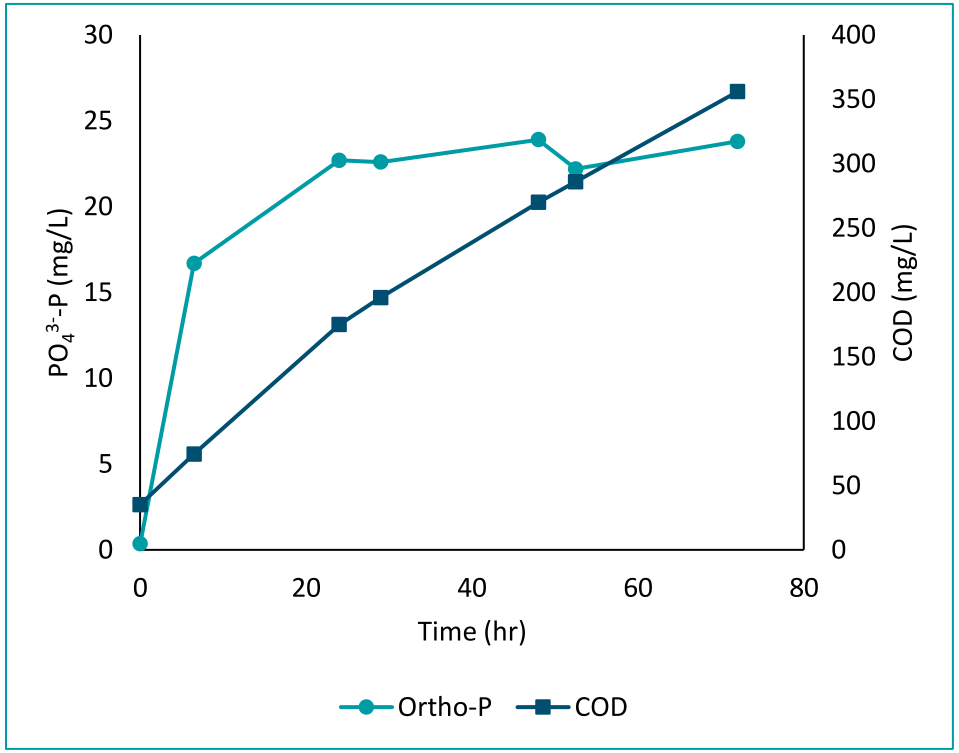
Duration: 24h-72h *

After Test

Chemical Analysis

Primary:
- Ortho-P, NHx-N, VFA, sCOD, ffCOD, fCOD in all samples
- TSS &VSS at beginning/end

Optional:
- Glycogen, PHAs
- P release, P uptake tests on each samples

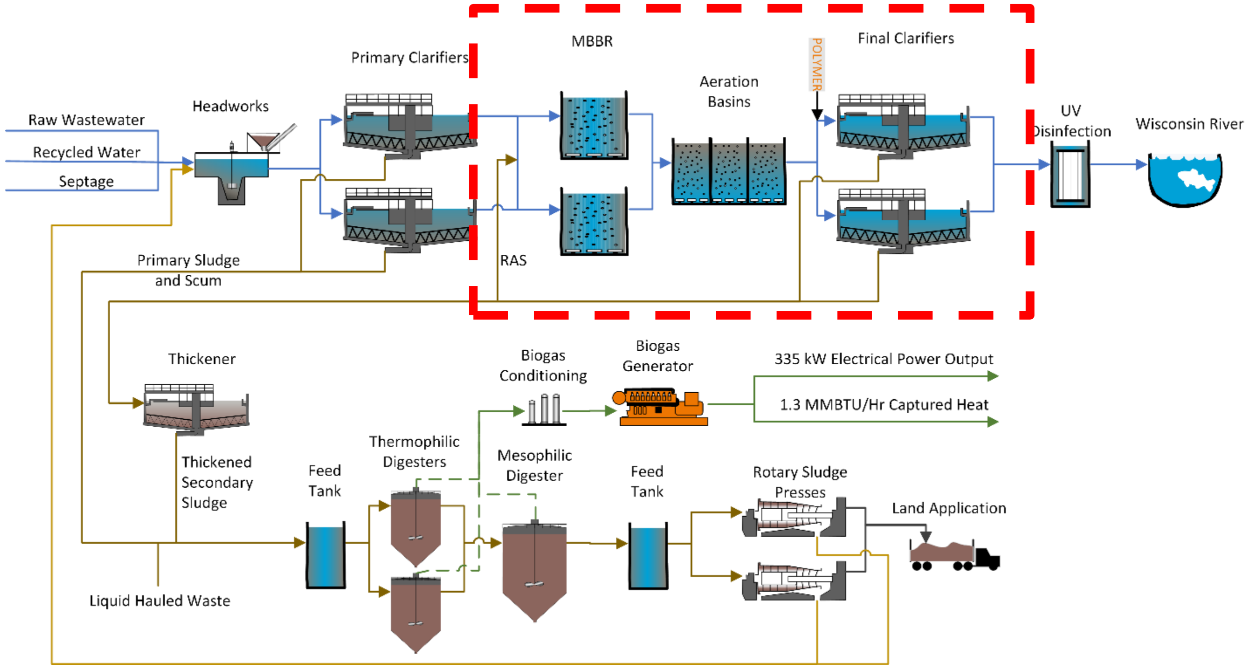


Generate a RAS fermentation rate in mgCOD/gVSS-hr

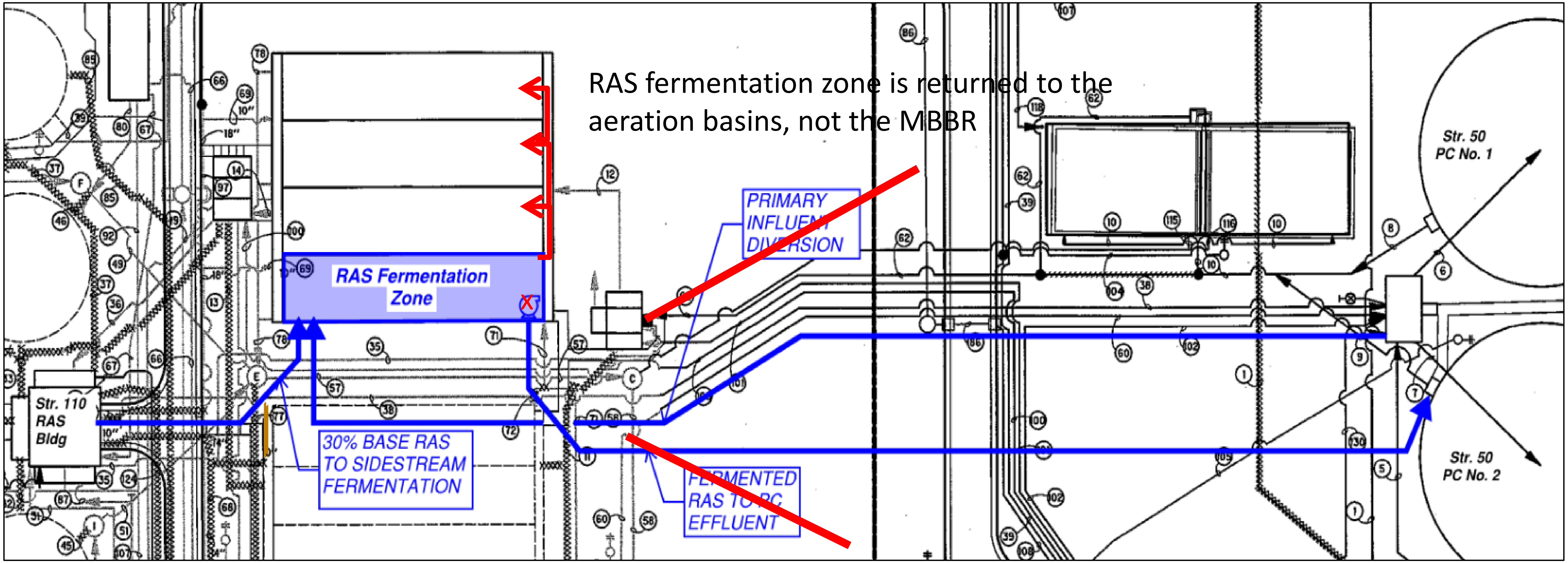
 

Case Study

Wisconsin Rapids WWTP, Wisconsin Rapids, Wisconsin

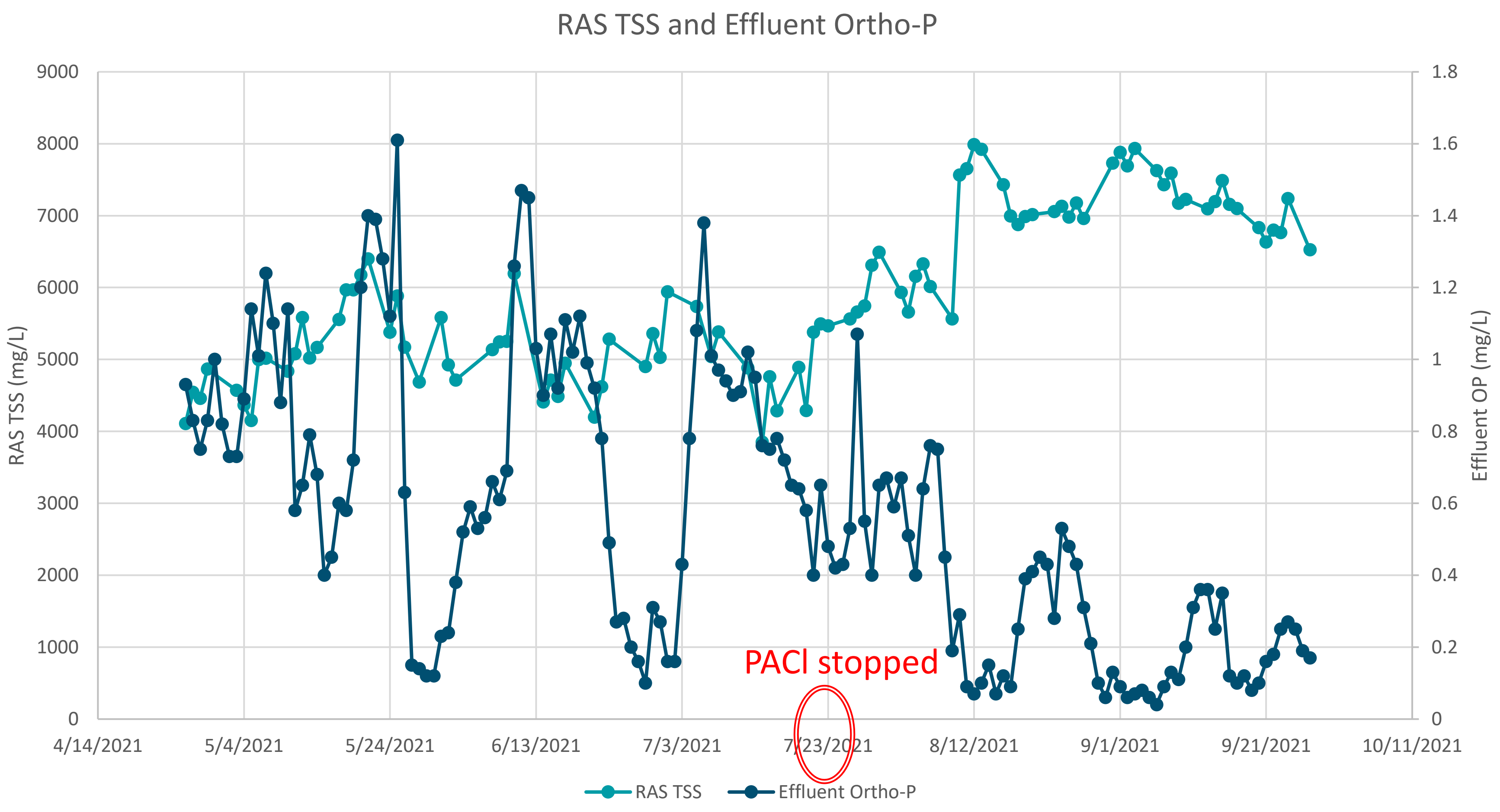


RAS fermentation testing design

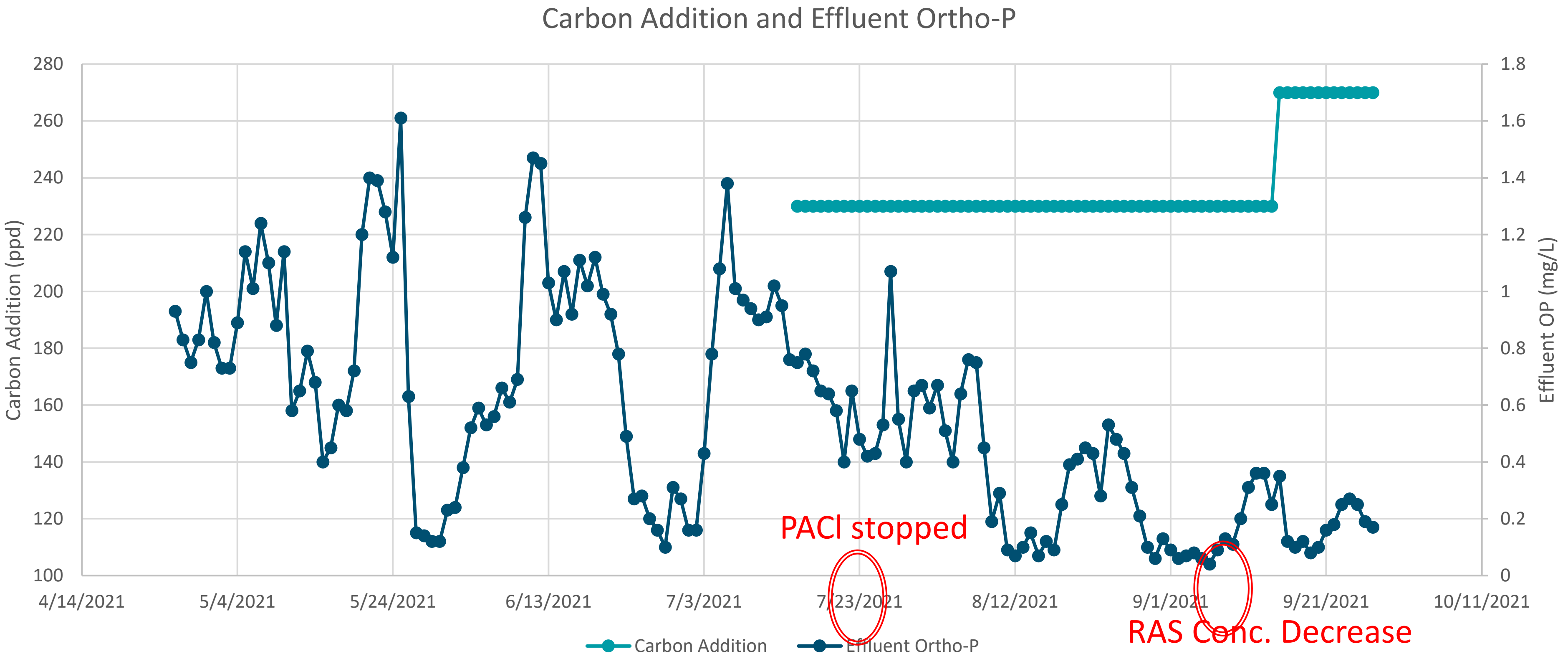


Cranberry wastewater feed to the fermentation zone

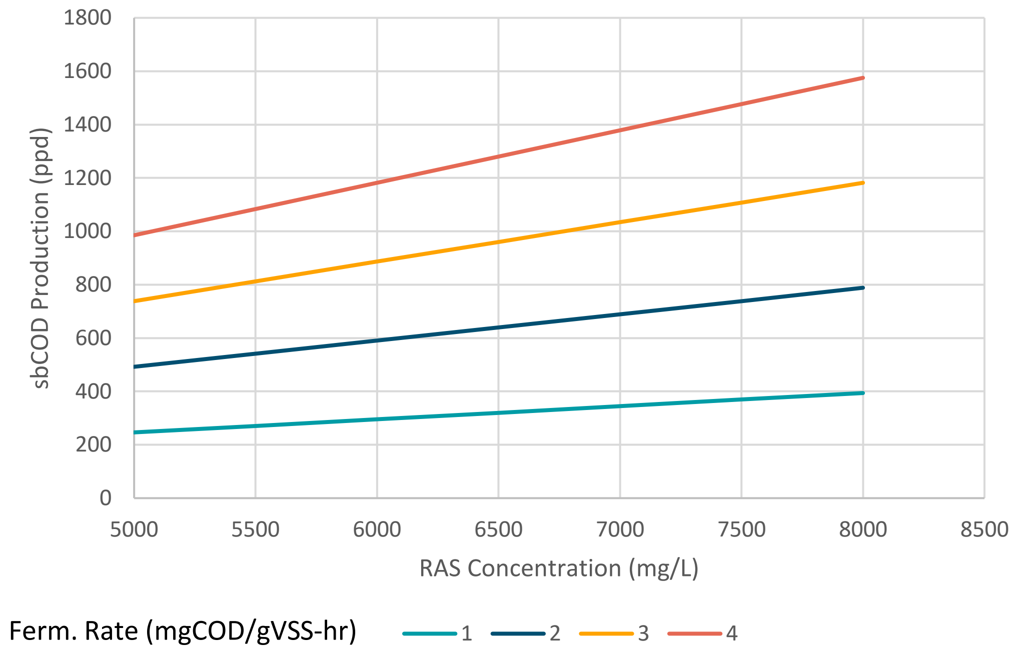
Overall performance has improved over time: RAS concentration and effluent

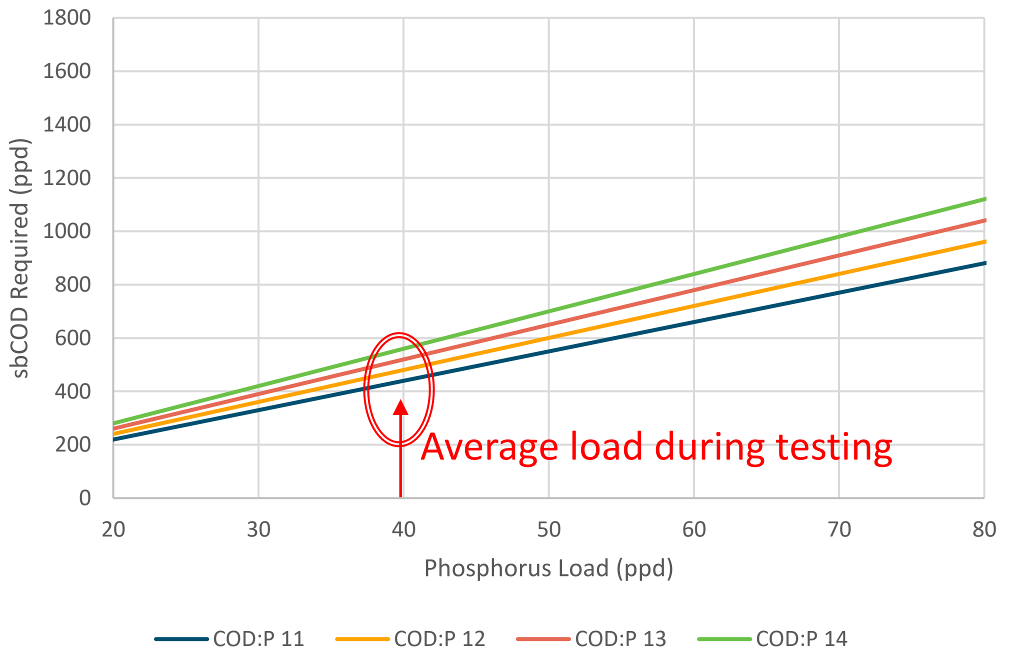


Overall performance has improved over time: carbon addition and effluent



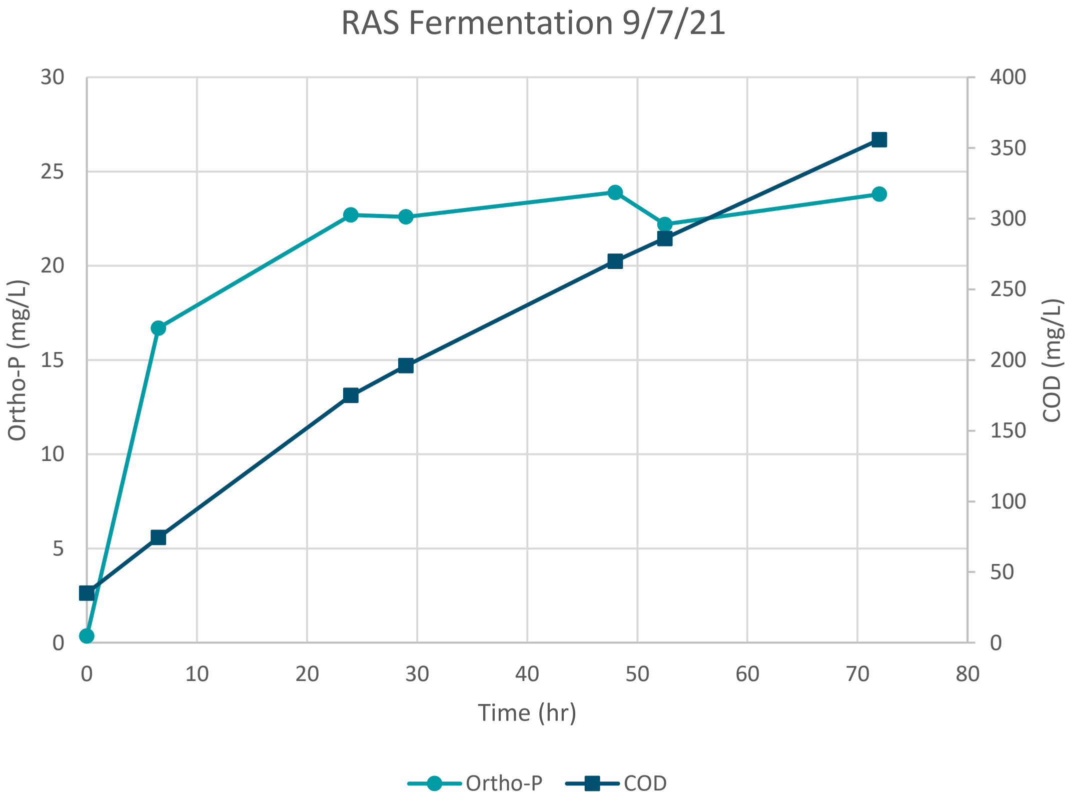
Can we think in terms of carbon needs for PAOs?

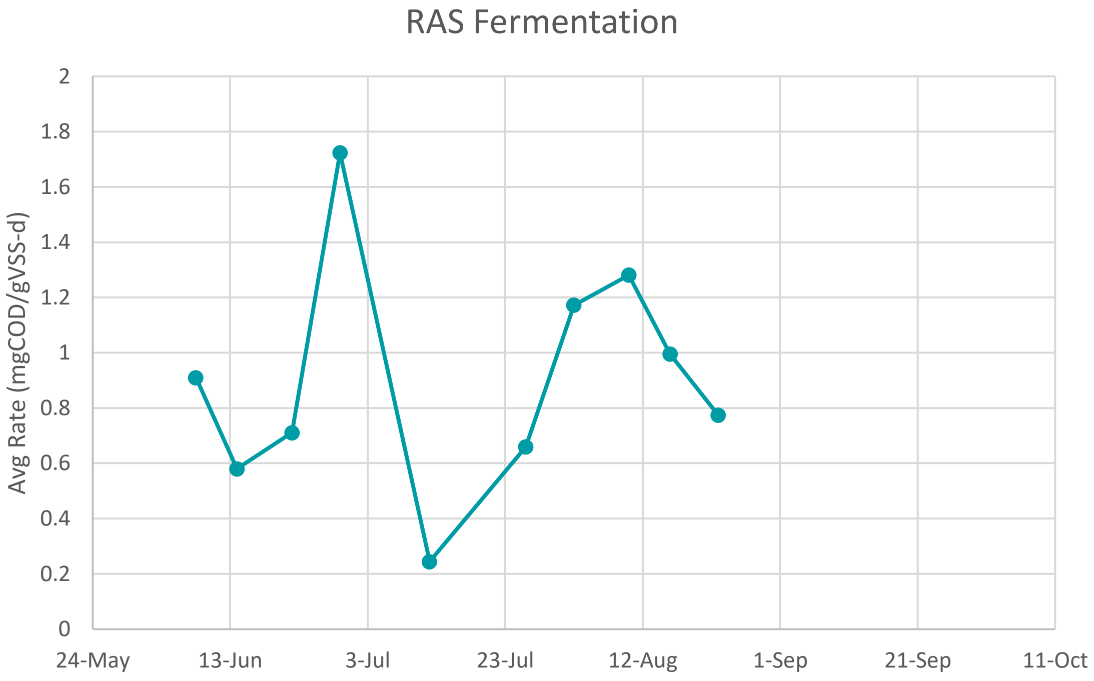




- System needs 420 to 570 ppd of carbon for EBPR
- RAS nitrate is 10 mg/L, which requires an additional 50 ppd of carbon

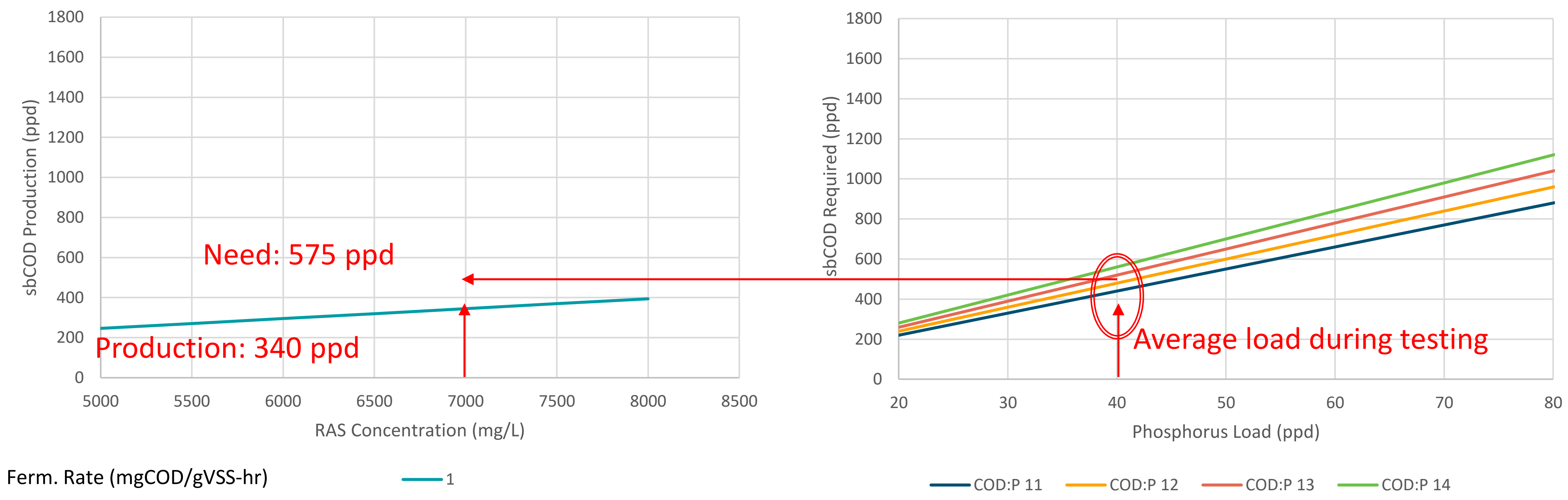
RAS fermentation rate has been measured over time





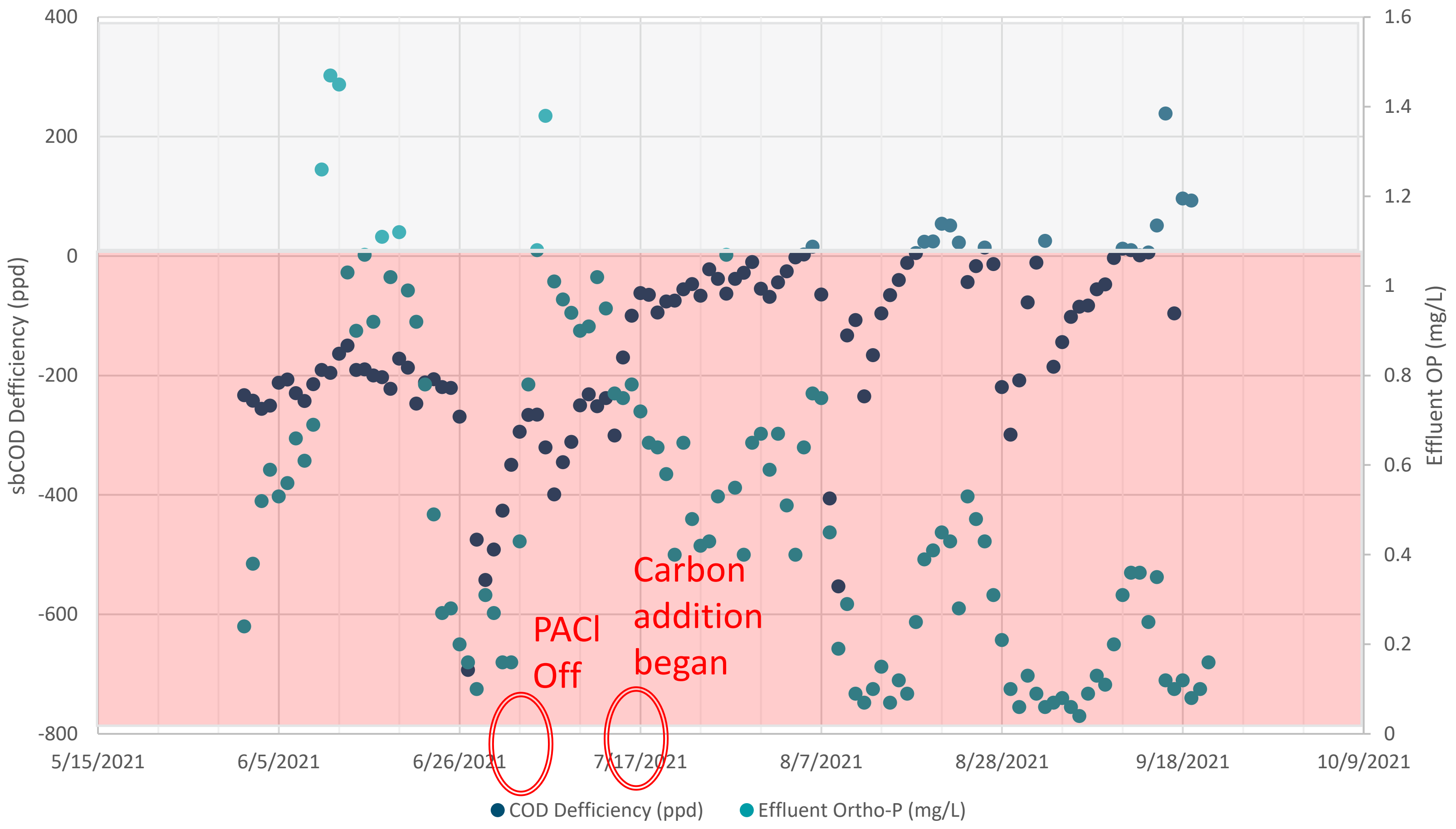
- Average rate: ~1 mgCOD/gVSS-hr

Can we think in terms of carbon needs for PAOs?

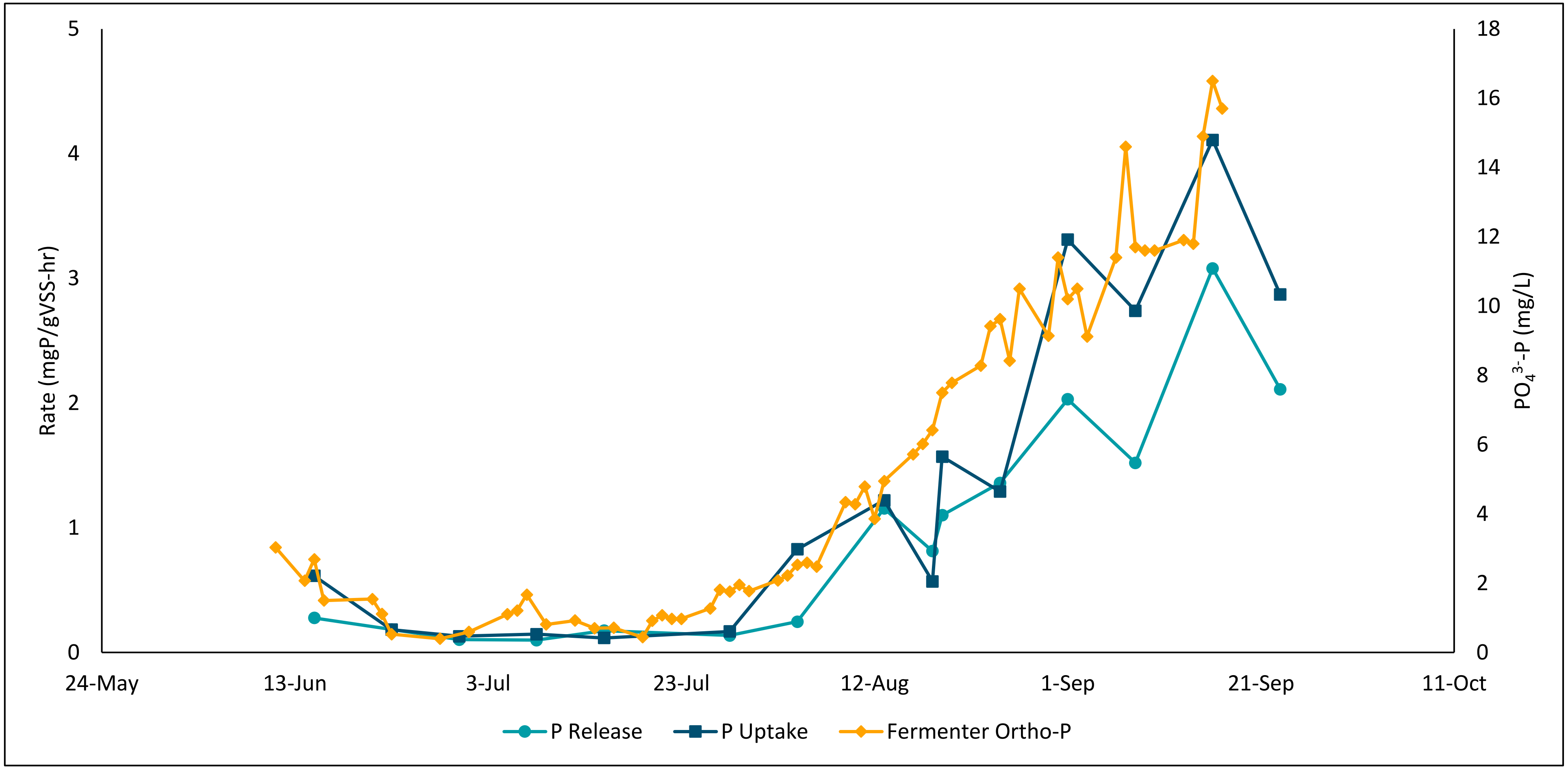


- Rate testing and mass balance would indicate an average shortage of ~235 ppd of carbon

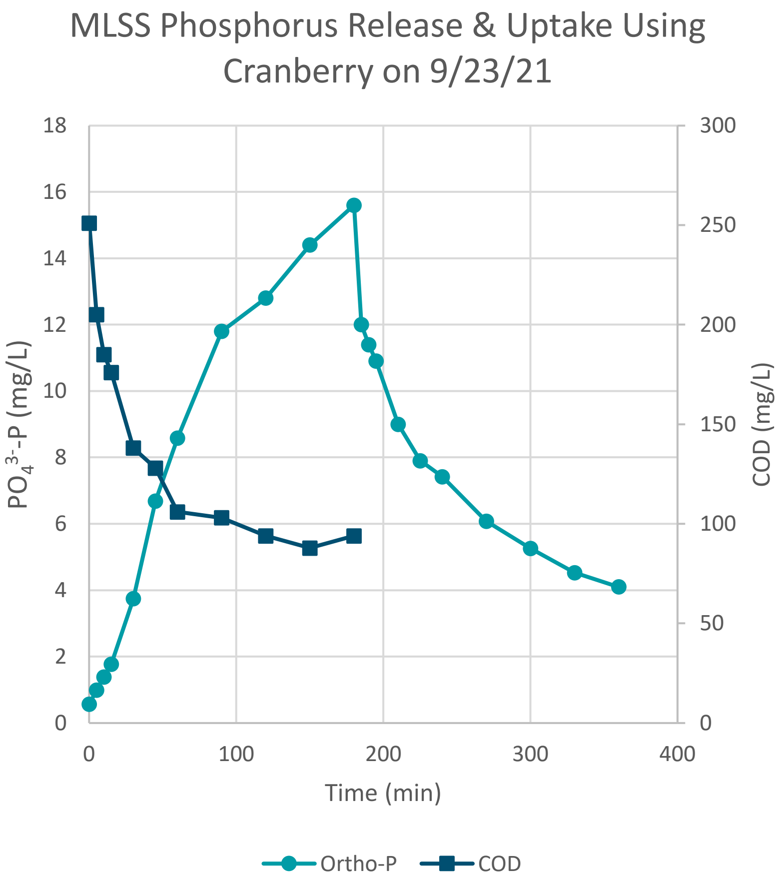
Carbon balance is correlating to overall process performance

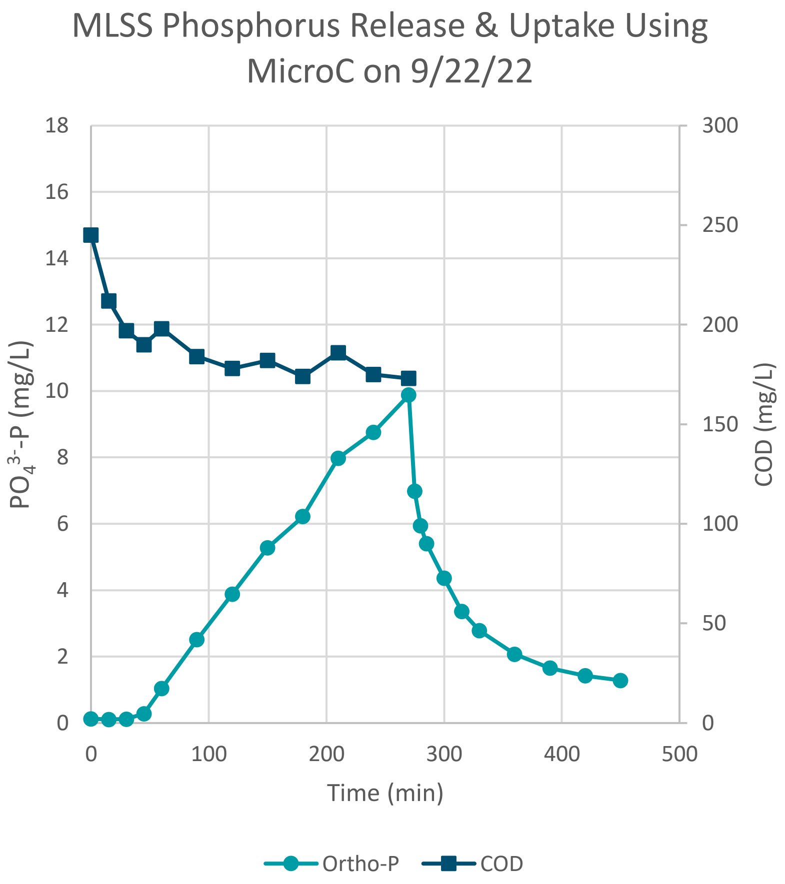


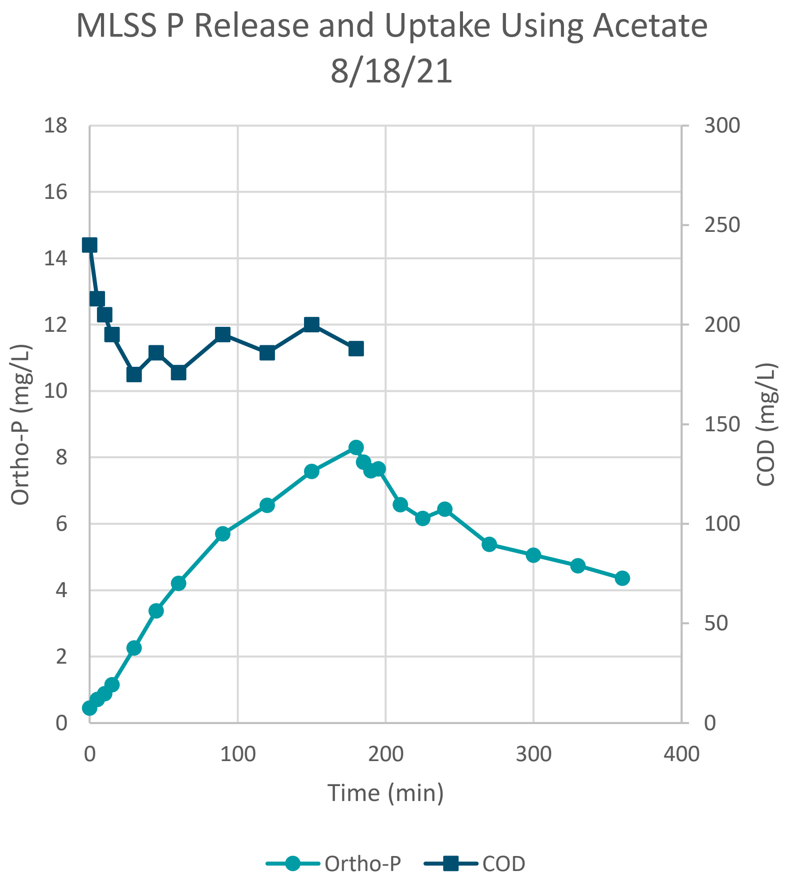
Release and uptake can also be monitored over time to assess carbon efficiency



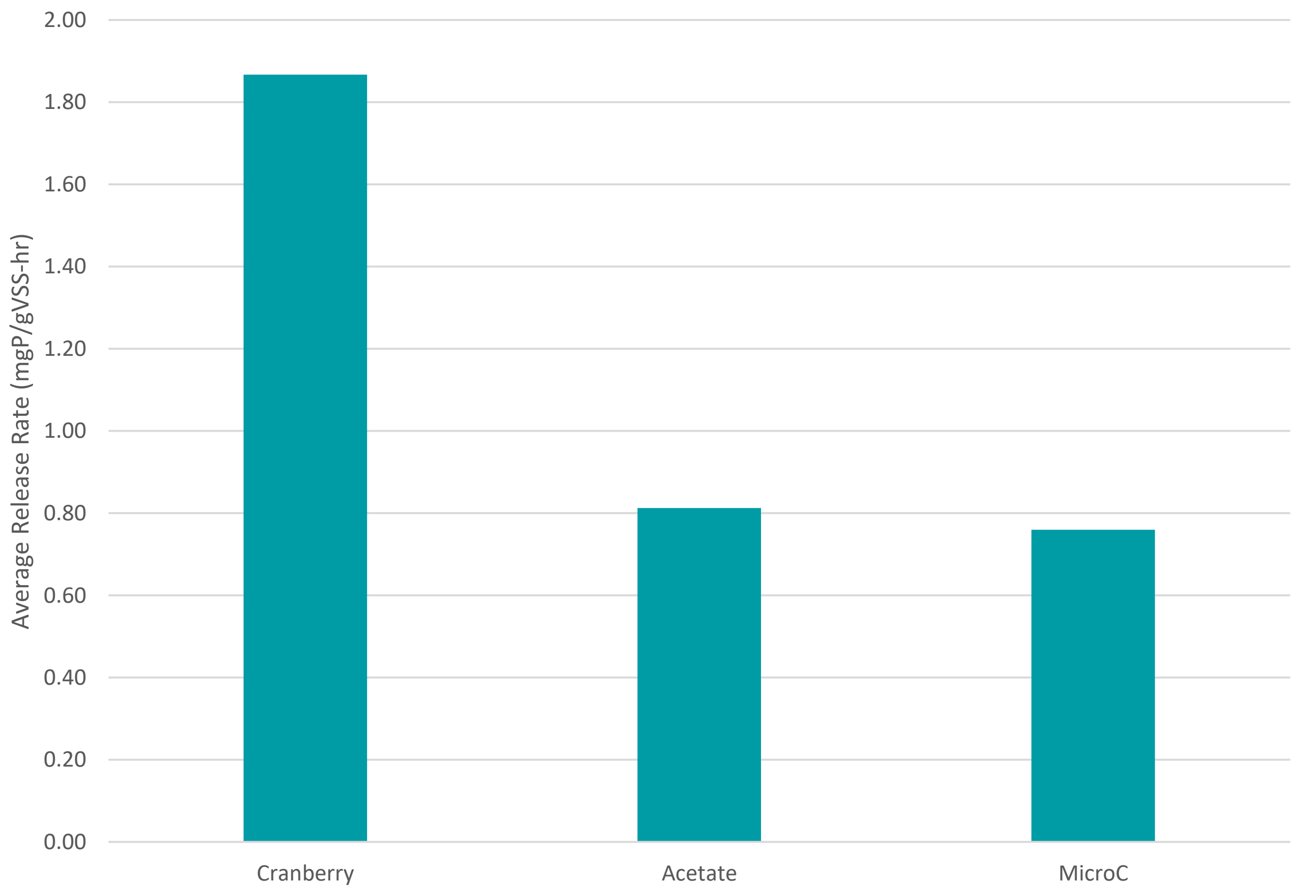
Carbon source impact has also been investigated with bench-scale testing



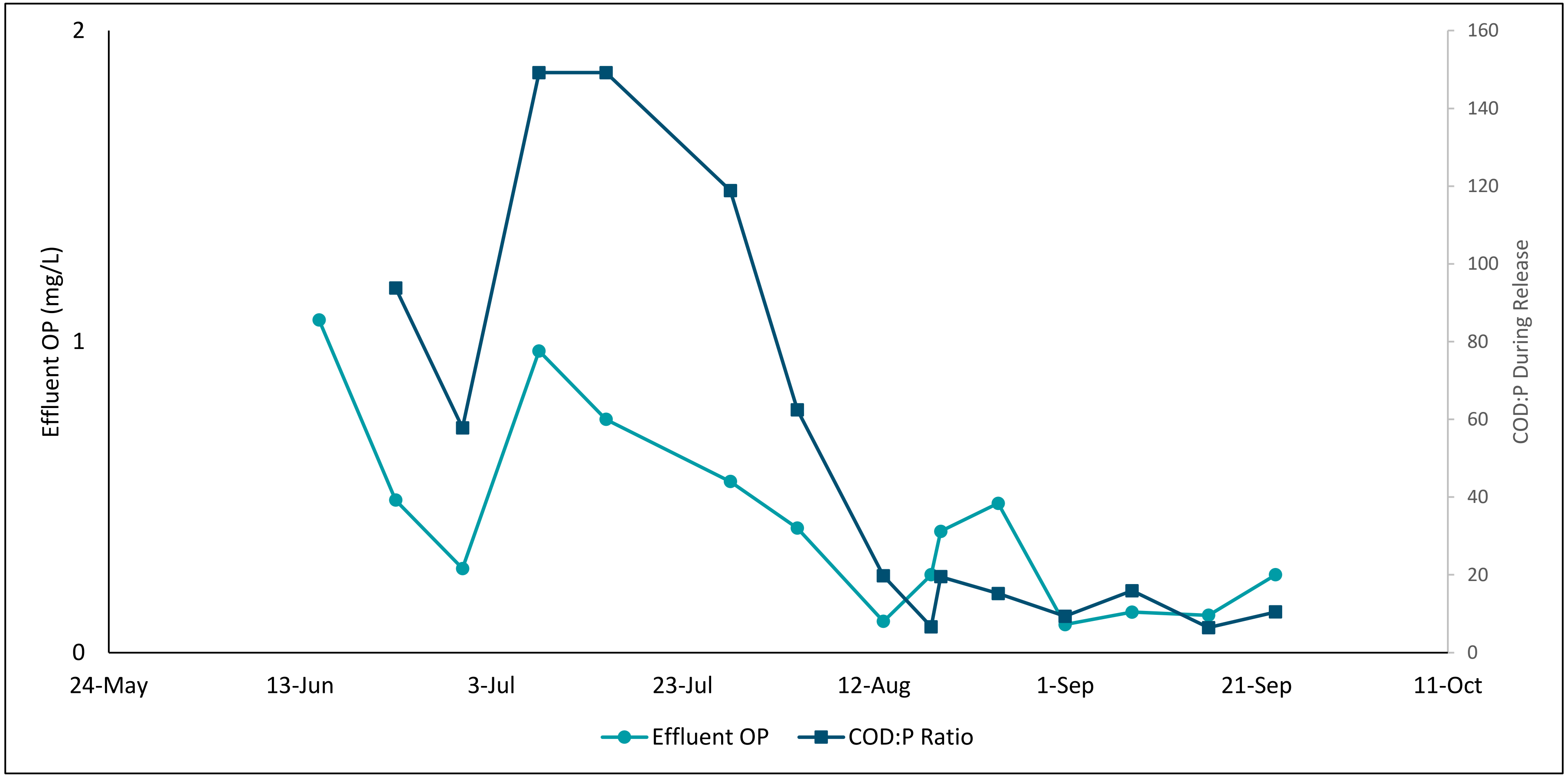




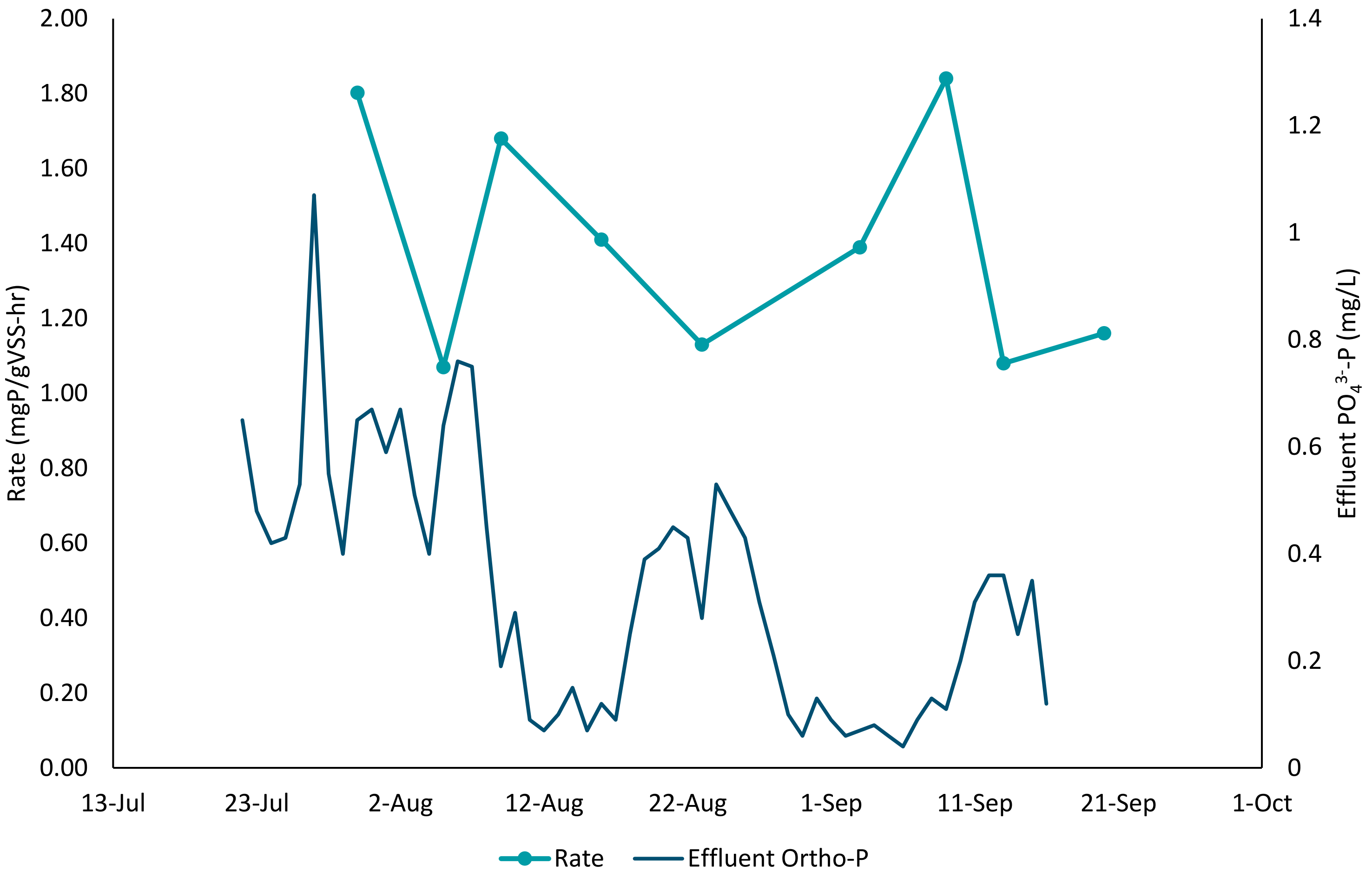
Is the RAS fermenter ecology adapted to cranberry juice (a.k.a. sugars)?



Carbon efficiency can also be examined over time



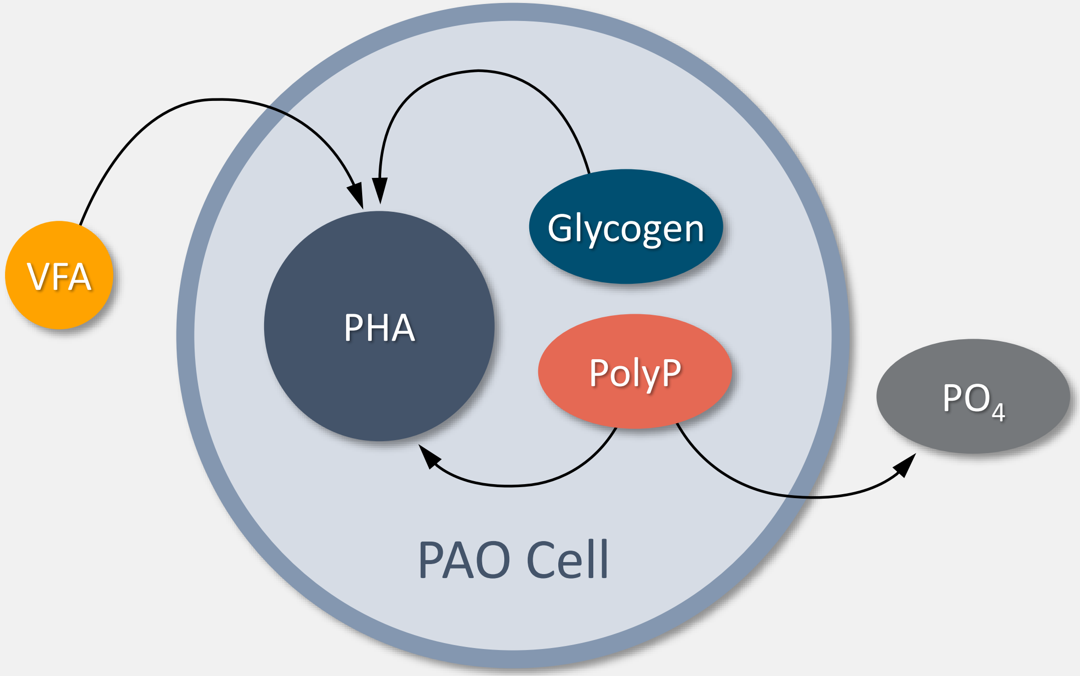
Residual phosphorus uptake can also foreshadow carbon shortage



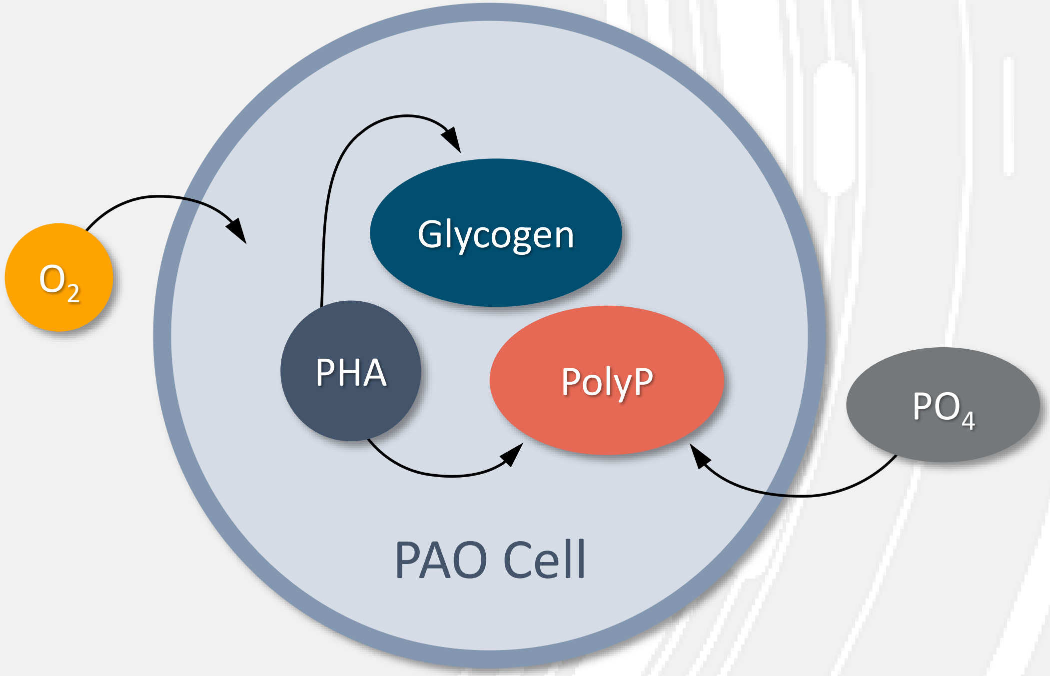
Summary

EBPR health should focus on assessing carbon cycling in PAOs

Anaerobic Conditions



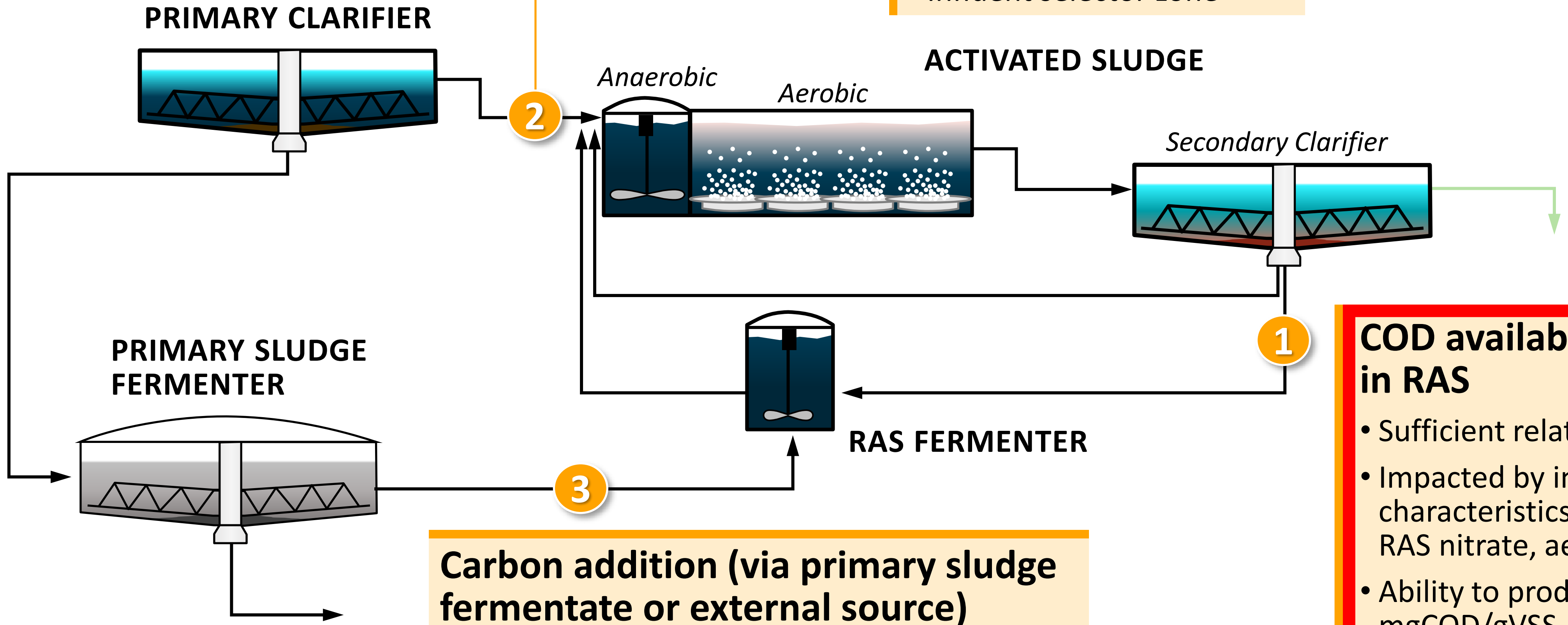
Aerobic Conditions



How do we better understand what is limiting PAO function?

Knowledge of the Whole Plant COD Balance is critical for EBPR (especially S2EBPR)

Influent rbCOD & VFA
- Influent selector zone



COD available from VSS in RAS
- Sufficient relative to influent P
- Impacted by influent characteristics, RAS nitrate, aerobic SRT
- Ability to produce 1 to 4 mgCOD/gVSS-hr

Carbon addition (via primary sludge fermentate or external source)
- Controlled dosing to sidestream tank

How many pounds of COD do we need for PHA charging & how do we get that COD?

Relatively simple rate testing can provide critical carbon balance information

- Simple apparatus
- Chemical needs: carbon source and orthophosphate
- Analytics: COD, phosphorus, nitrate
- Largest challenge: sample filtration

Thank you

Comments or questions, please contact:

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For more information, visit www.waterrf.org