BUILDING A WORLD OF DIFFERENCE

NEWEA – ANNUAL CONFERENCE & EXHIBITION

MORE EFFICIENT MECHANISMS OF BIOLOGICAL PHOSPHORUS REMOVAL

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January 22-25 | Boston MA

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NEWEA 2017 Annual Conference & Exhibit

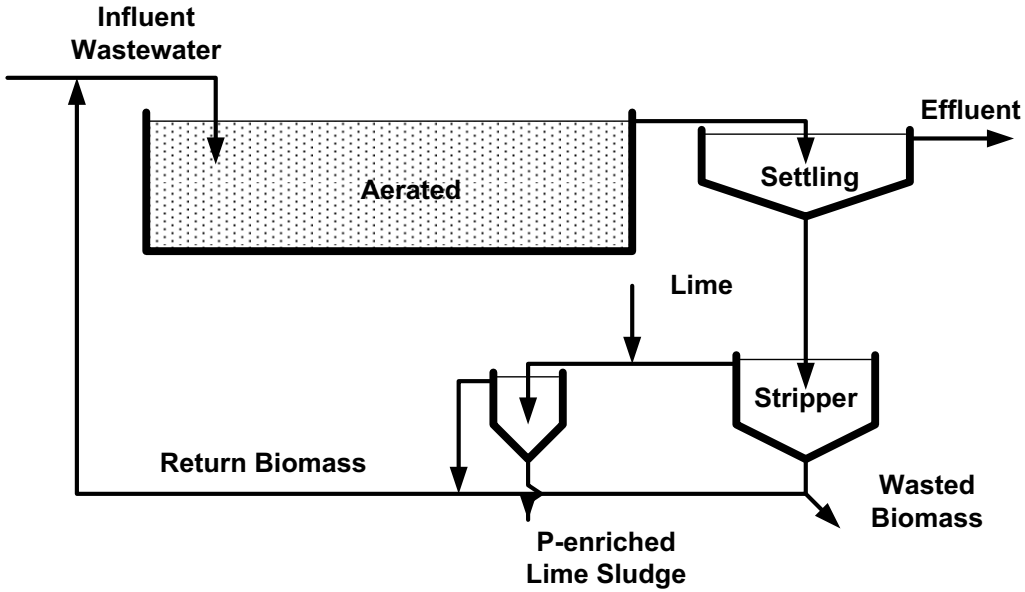
January 22 – 25
Boston Marriott Copley Place
Boston, Massachusetts

AGENDA

- History of EBPR
- Proposed mechanisms
- Alternative flowsheets
- Possible limitations of existing practices
- Problems with modeling alternative flow sheets
- Proposed remedies

SOME EARLY OBSERVATIONS

- Hi-rate no nitrification
- 30 to 40 h in Stripper
- Supernatant high in P treated with lime
- All primary effluent to aeration basin
- RAS thru deep anaerobic conditions

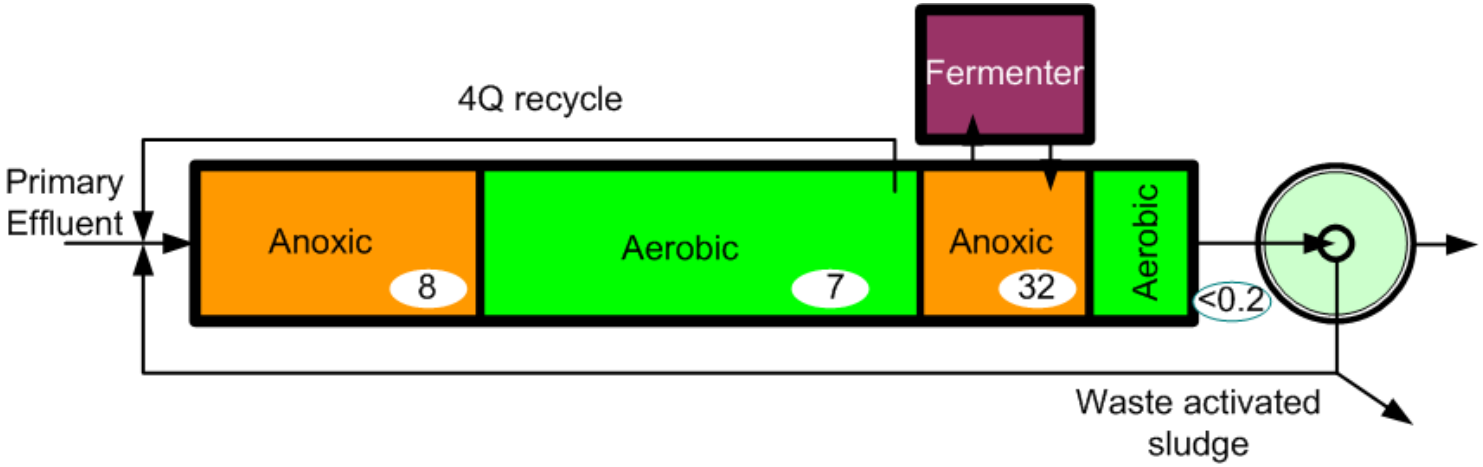


Phostrip Process

Levin et al (1975)

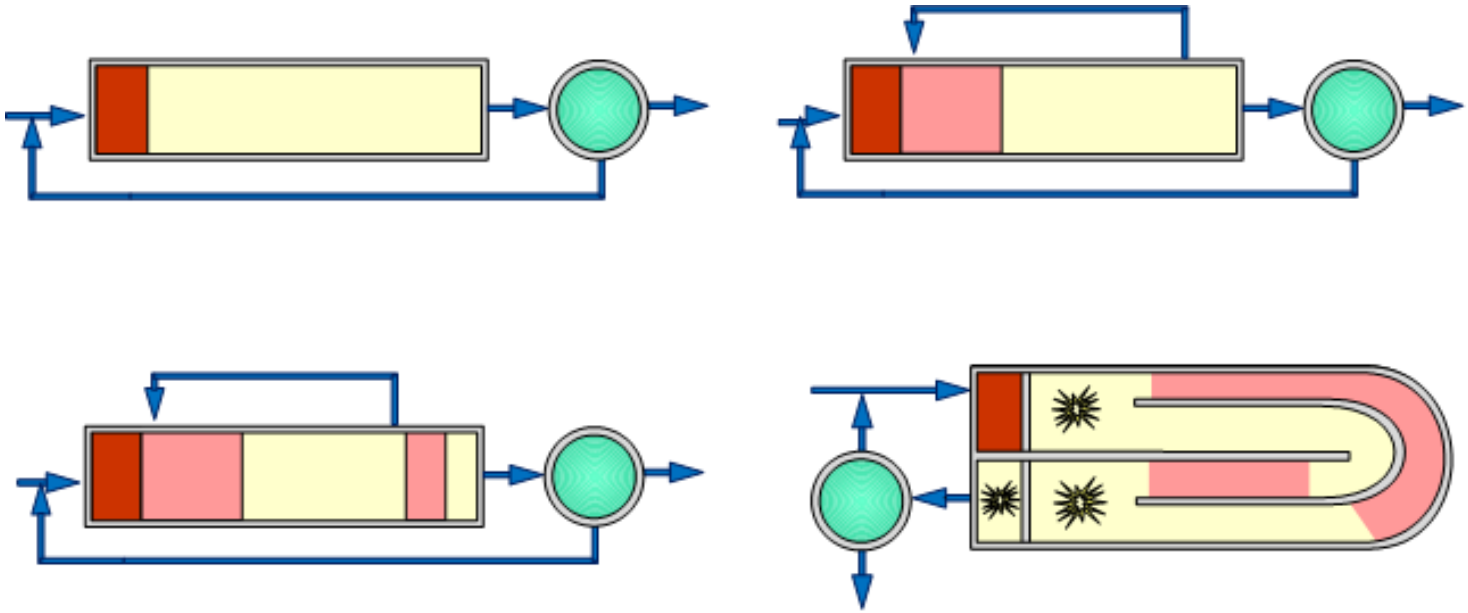
MIXED LIQUOR FERMENTER (MLF)

- Fermenter resulted from basin configuration and not deemed important
- Excellent phosphorus removal resulted
- Note orthophosphates profile through plant
- Performance could not be replicated in laboratory
- Barnard suggested organisms (PAO) should pass through anaerobic phase with low ORP which triggered EBPR
- Suggested Phoredox process by adding anaerobic zone up front



Barnard 100 m^3/d pilot 1972

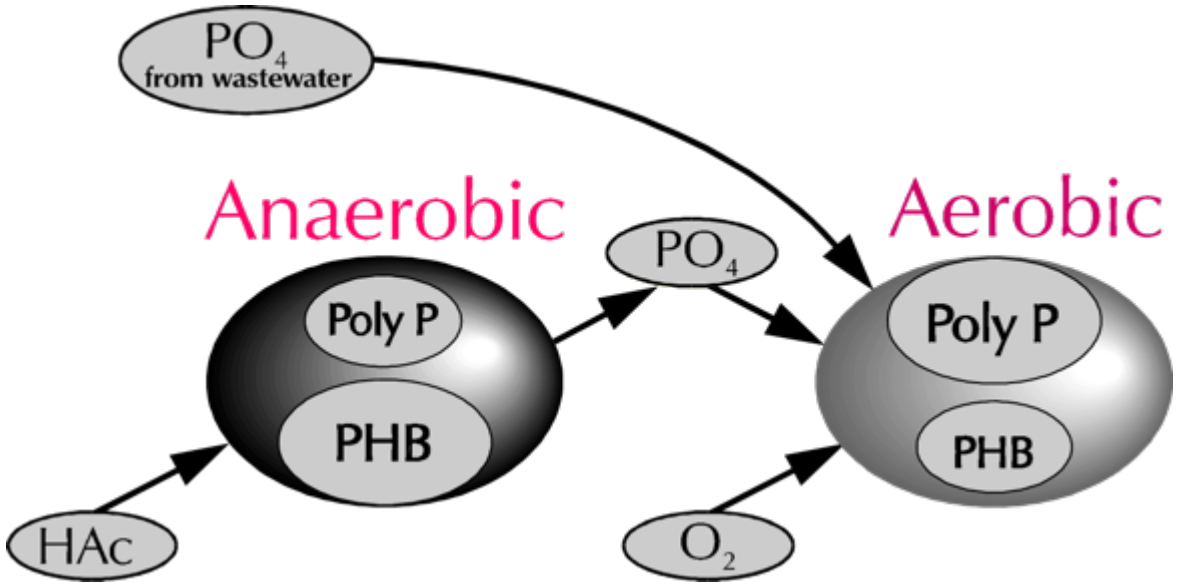
PHOREDOX (AKA AO) CONCEPT OF PASSING ALL PRIMARY EFFLUENT THROUGH ANAEROBIC ZONE



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

FUHS & CHEN (1975)

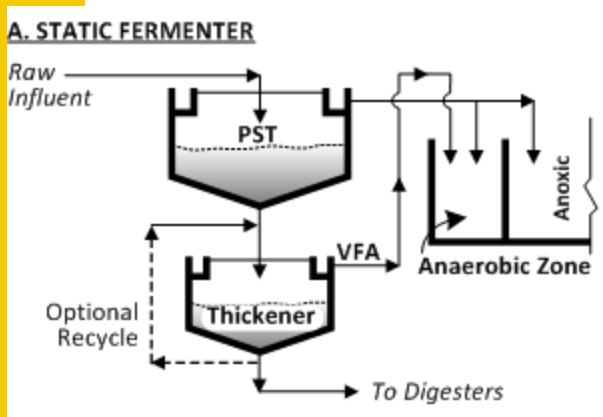
- Studied the Pho-strip process
- Suggested PAO take up P when aerobic, use that energy to take up VFA in anaerobic zone
- Identified PAO as Acinetobacter
- Mechanisms further developed by Comeau & Wentzel

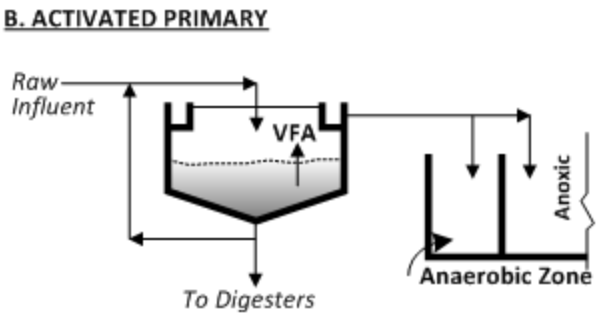


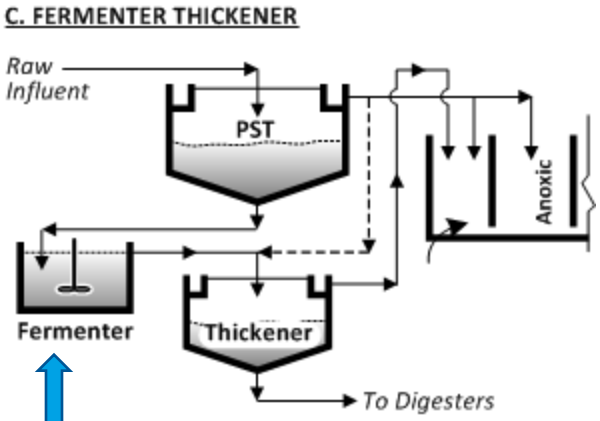
As adapted by Comeau & Wentzel

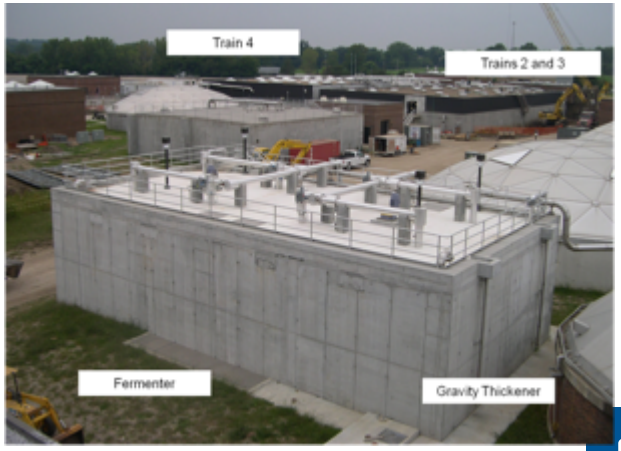
Problem – not always sufficient VFA in primary effluent

VFA FROM FERMENTERS









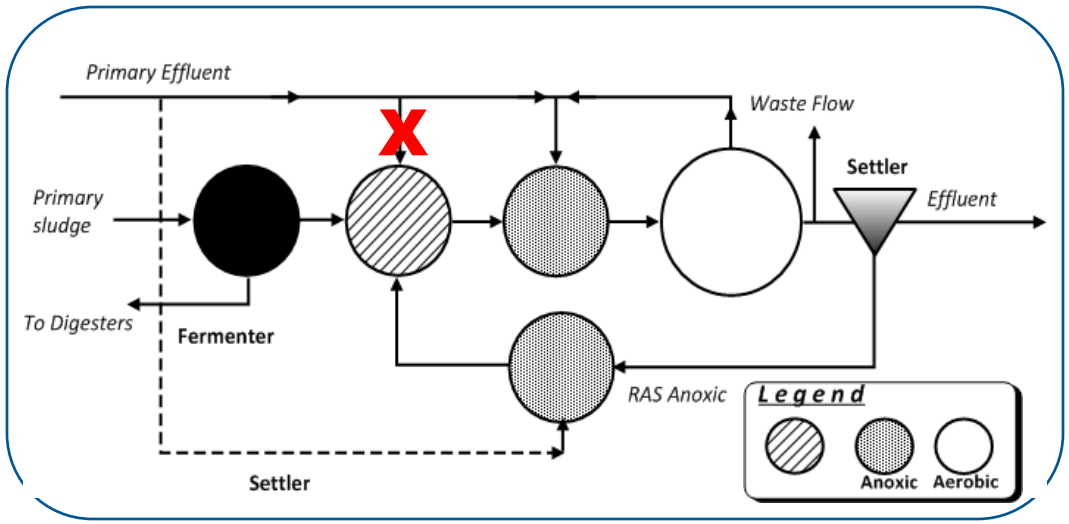
VIEW OF KELOWNA B.C.

FURTHER STUDIES IDENTIFIED CANDIDATUS ACCUMULIBACTER AS THE DOMINANT PAO

- "…it was incorrectly considered that PAOs were of the genus *Acinetobacter*…. or *Tetrasphaera* " by Fuhs & Chen and others*
- "More recently, culture-independent methods have shown *Accummulibacter phosphatis* … is a PAO which can be grown in enriched cultures …"*
- "For the purpose of design it will be considered that anoxic P uptake is not significant"*

*IWA – Biological Wastewater Treatment - Principles,, Modeling and Design Henze *et al*

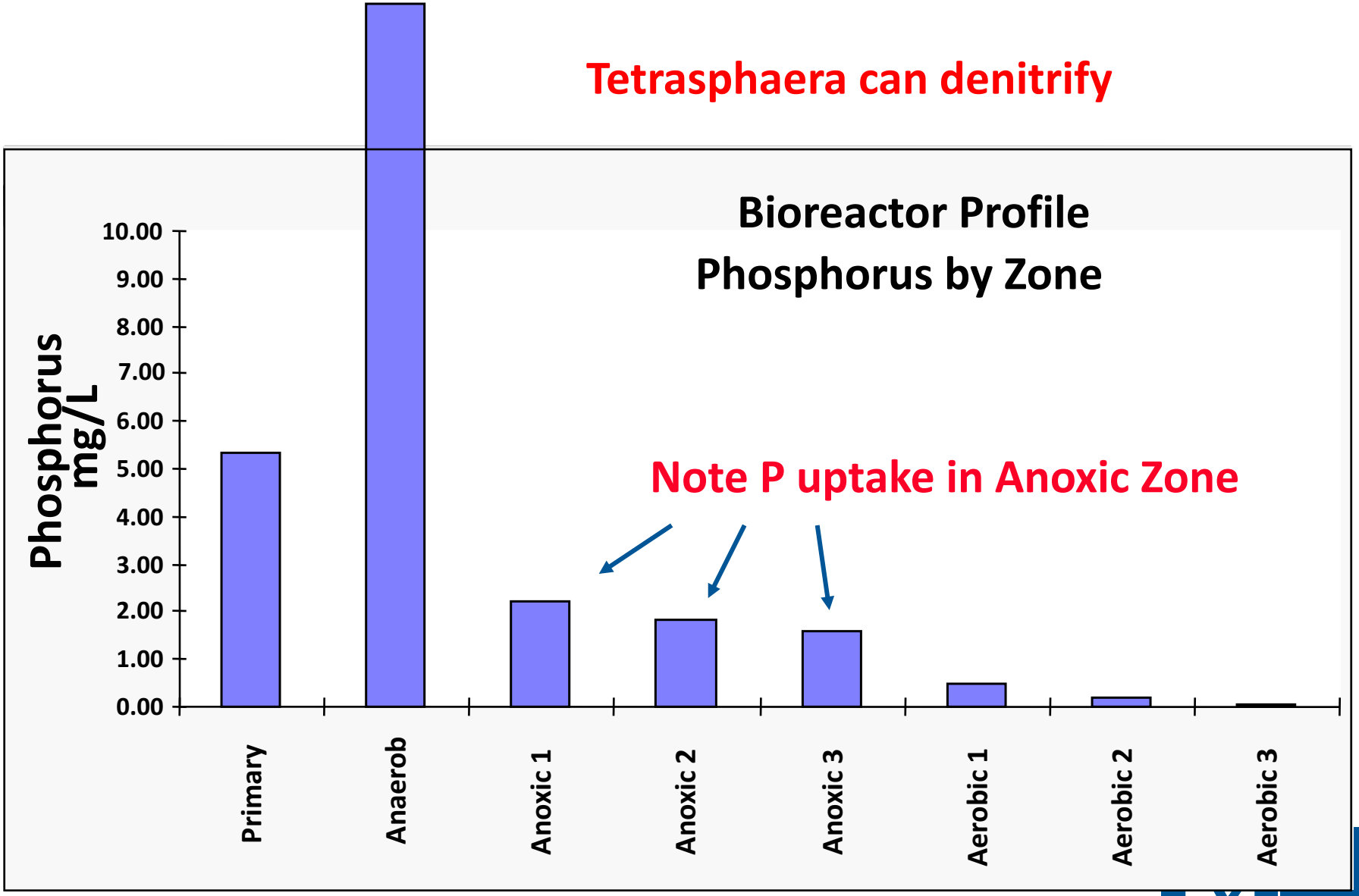
Westside Kelowna BC (Westbank)



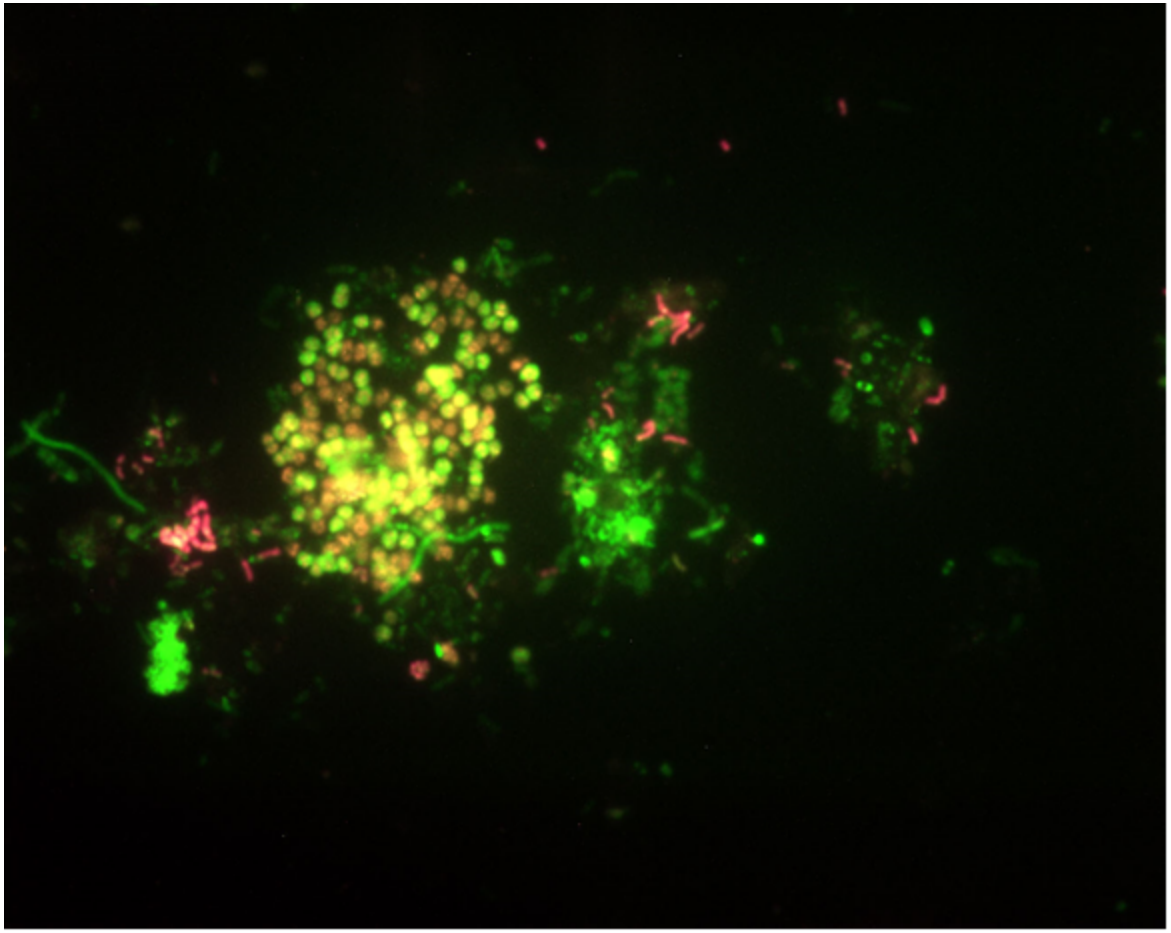
TN < 6 mg/ℓ
BOD < 5 mg/ℓ
TSS < 2 mg/ℓ
TP < 0.15 mg/ℓ

WESTBANK WWTP

Tetrasphaera can denitrify



MIX OF ORGANISMS IN WESTSIDE PLANT

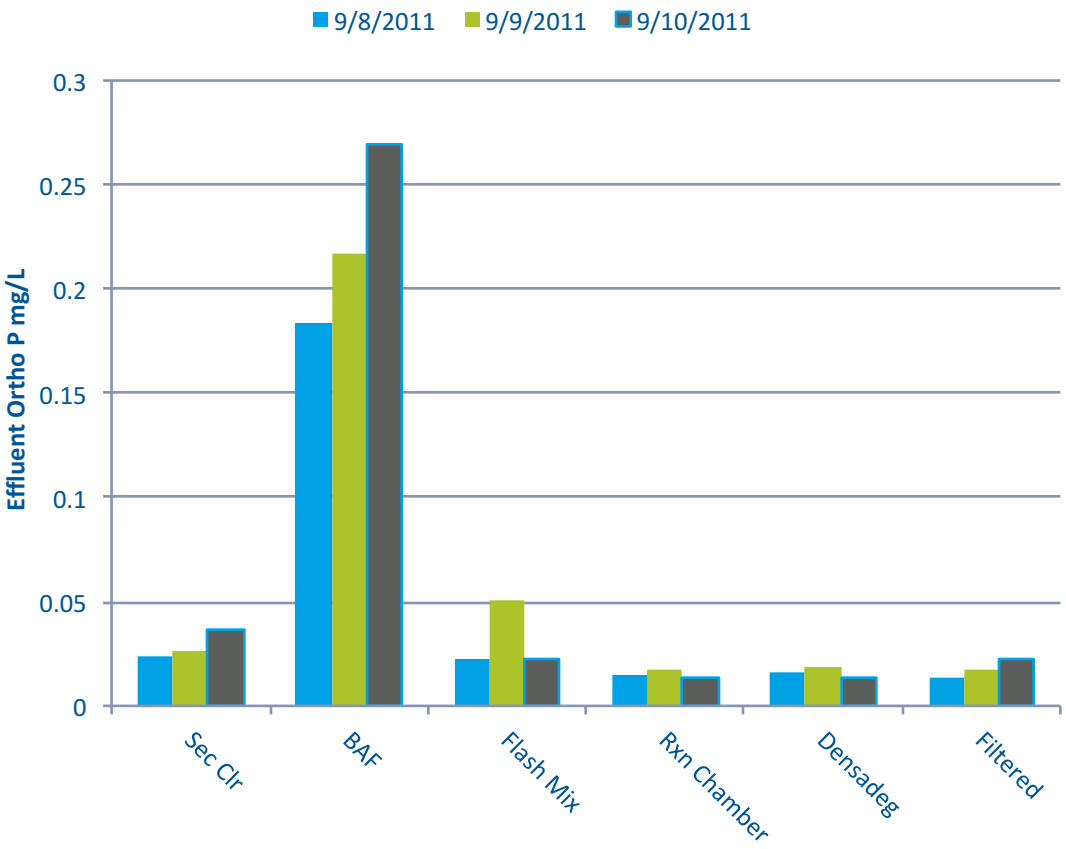


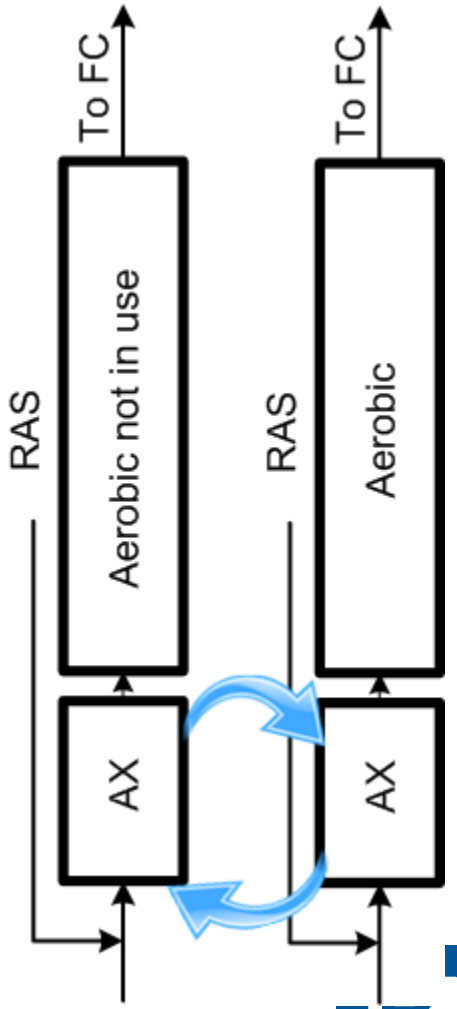
Dunlap et al 2015

FISH Image from WR WWTP Sludge with EUB mix (all bacteria) Shown in Green, Tet2-174 (Tetrasphaera clade 2B) in Orange, and Tet3-654 (Tetrasphaera clade 3) in Red.

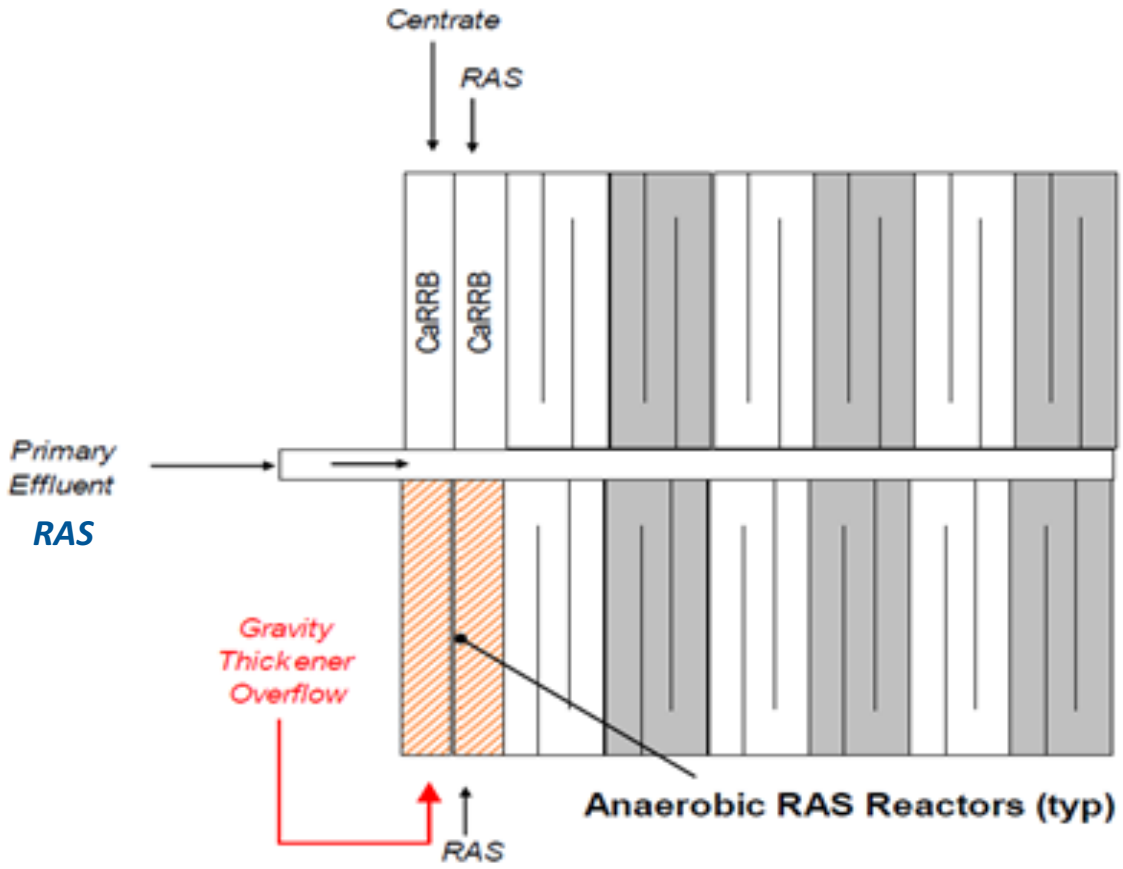
PHOSPHORUS REMOVAL WITH SIDE-STREAM FERMENTATION

Iowa Hill CO plant – From Chris Maher



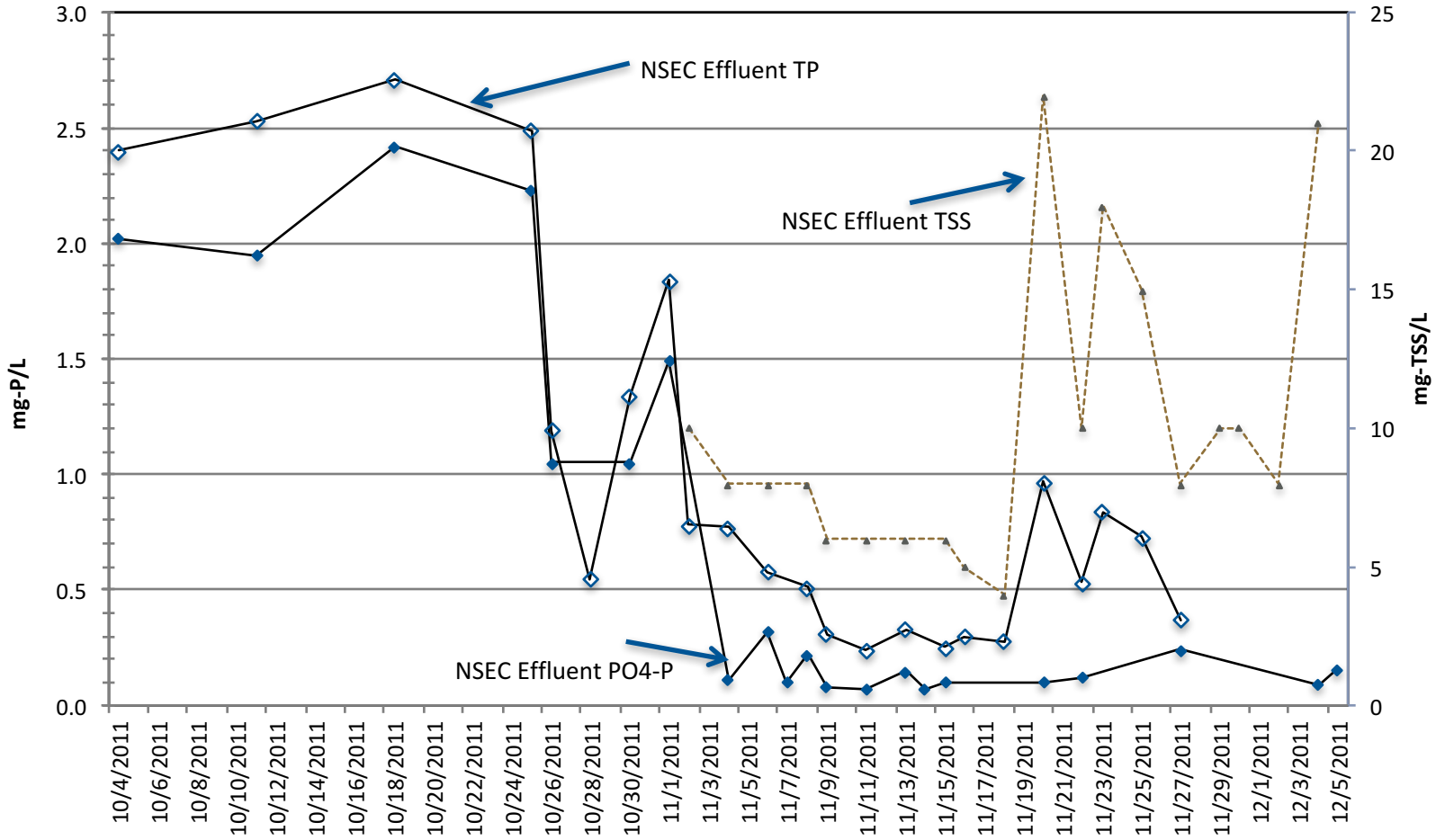


EXPERIMENT AT DENVER METRO



Cavanaugh, L., Carson, K., Lynch, C., Phillips, H., Barnard, J. and McQuarrie, J. (2012) A Small Footprint Approach for Enhanced Biological Phosphorus Removal: Results from a 106 mgd Full-Scale Demonstration. *Proceedings of the 85th Annual Water Environment Federation Technical Exhibition and Conference*, New Orleans, LA, October 2012.

PHOSPHORUS REMOVAL BY RAS FERMENTATION – DENVER METRO



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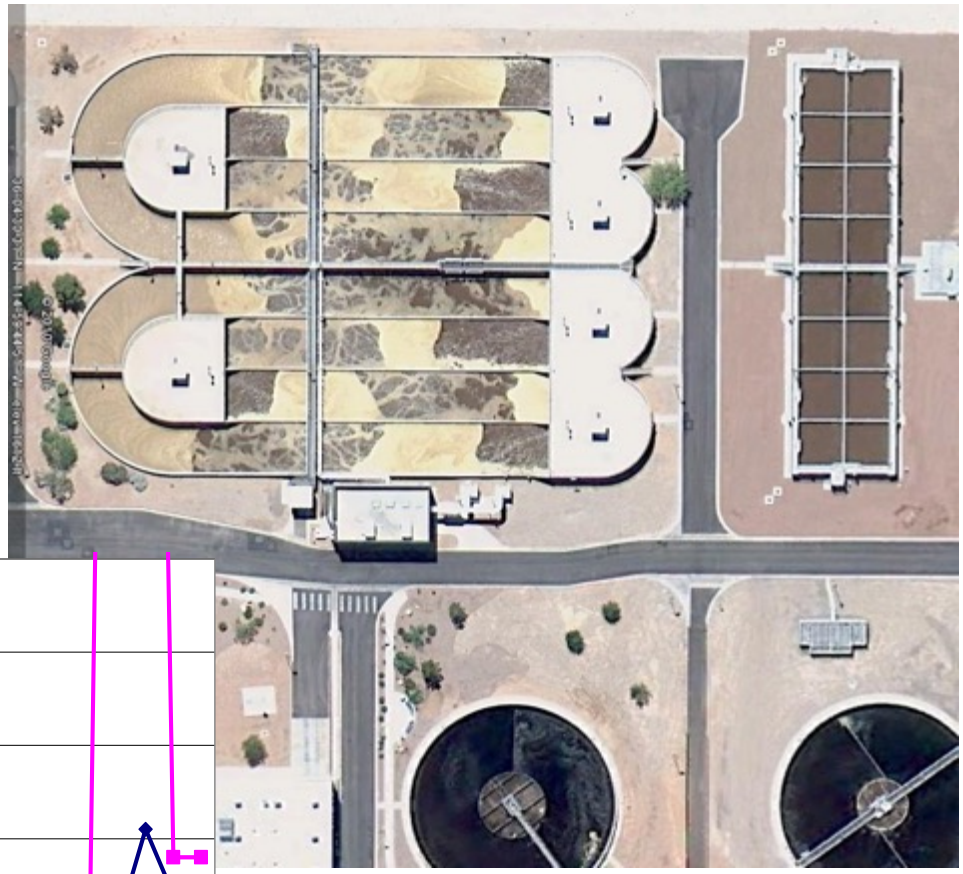
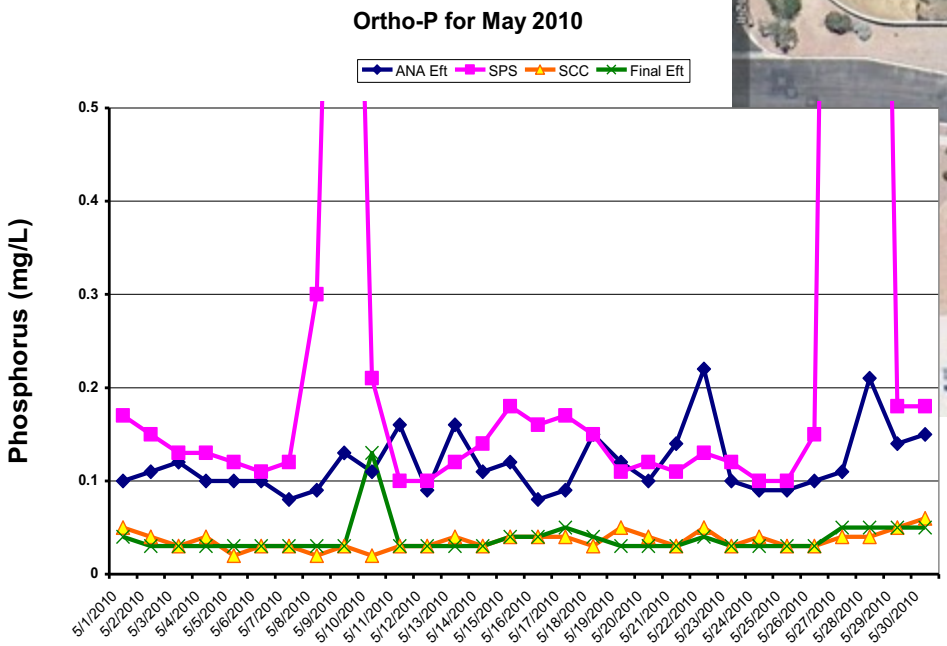
CAROUSEL PLANT HENDERSON NV 60 ML/D – UPGRADED TO BNR

Switching off a mixer in the anaerobic zone resulted in In-plant Fermentation





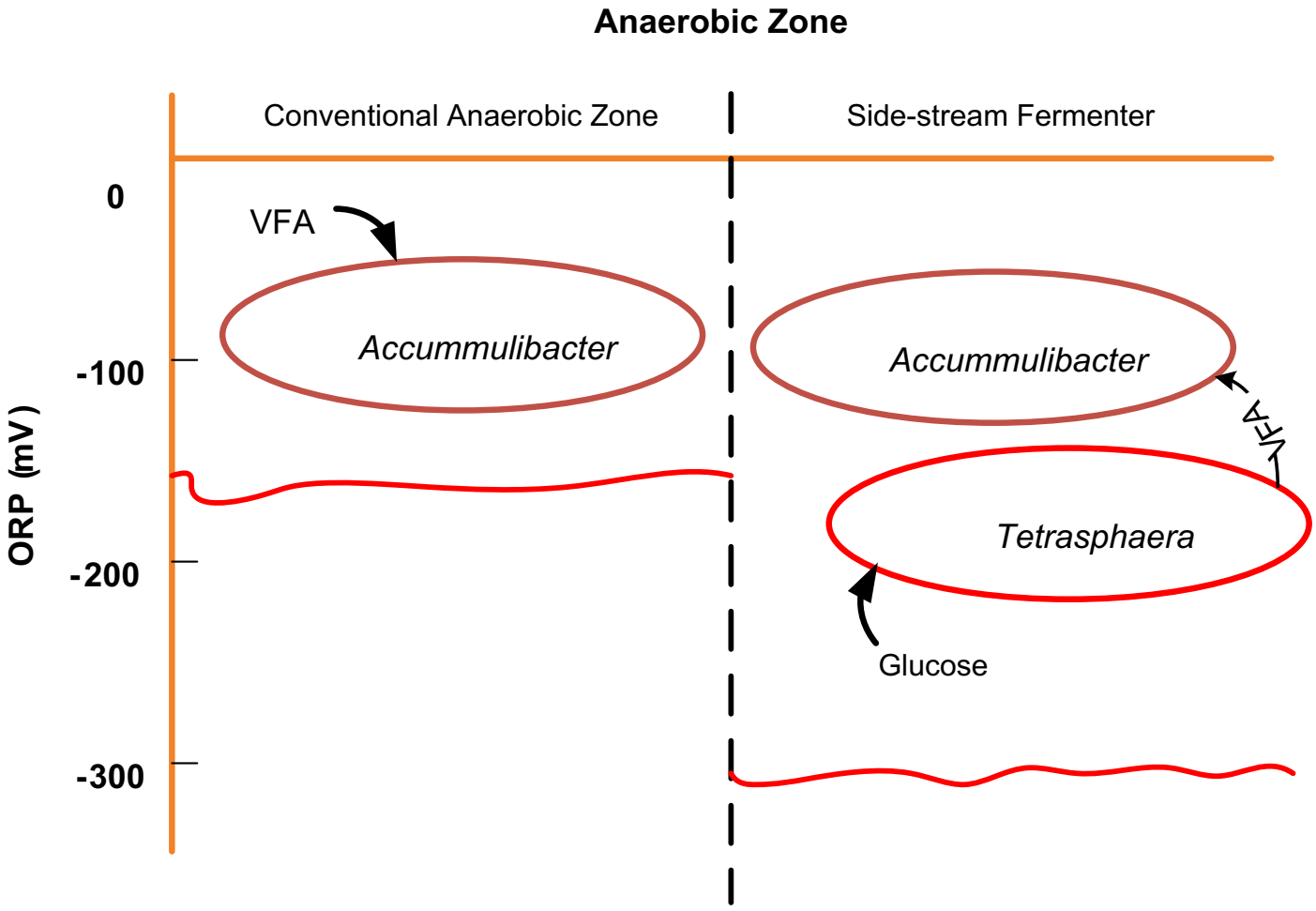
POSSIBLE LIMITATIONS OF EXISTING CONFIGURATION

- Were we perhaps selecting mostly for species of *Accumulibacter* that needed a supply of acetic & propionic acid
- They could have prevailed in standard anaerobic zones since conditions were not ideal for fermenting species like *Tetrasphaera*
- *Tetrasphaera* can ferment glucose and amino acids and other higher carbon forms and store phosphorus – Nguyen et al
- They actually produce VFA that allow a population of *Accumulibacter* to grow alongside them
- They can denitrify under anoxic conditions
- Why did we not grow them – not deep enough anaerobi conditions

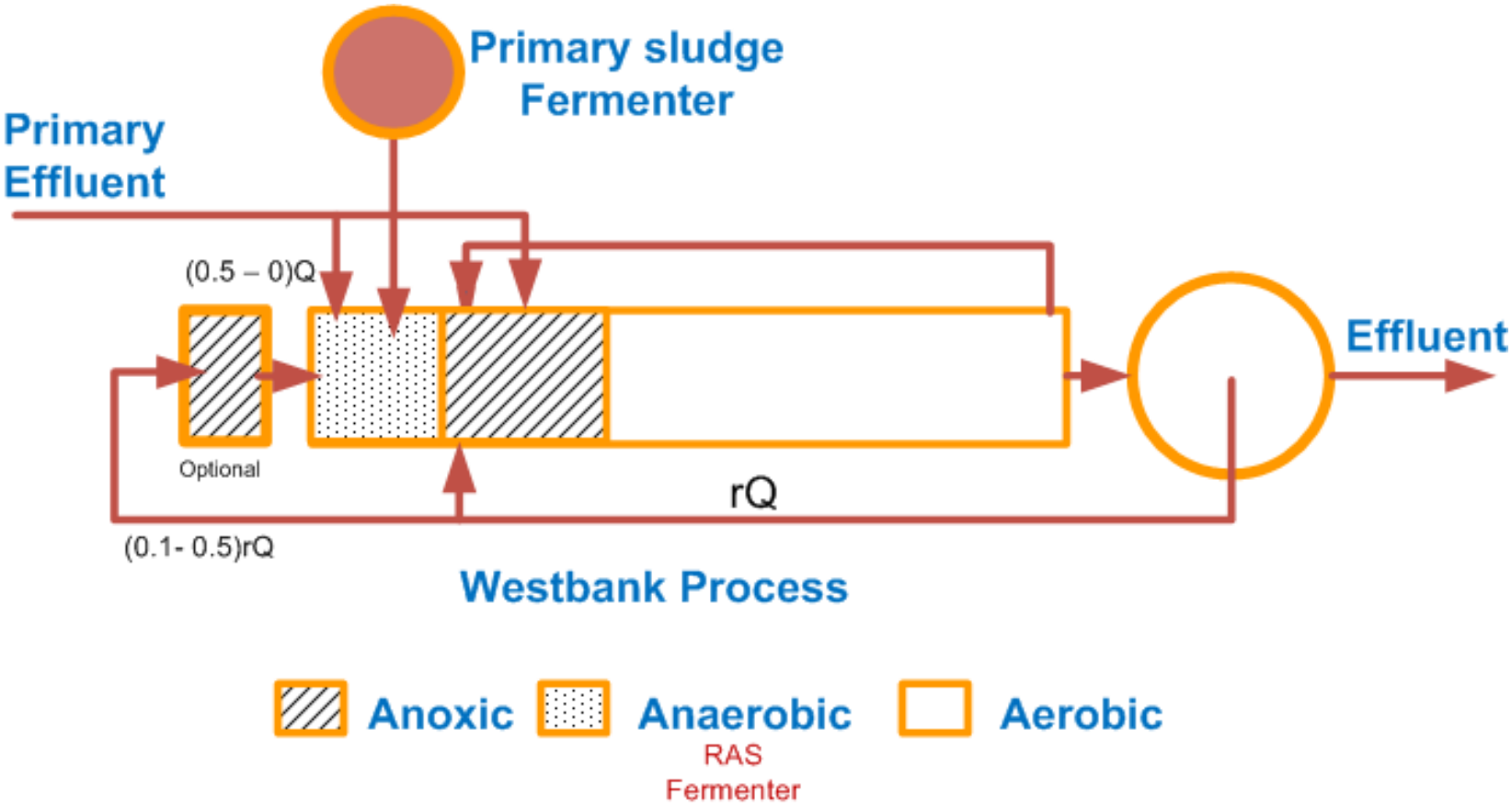
WHY DID WE MISS IT?

- It appears that we need an ORP of <-300 mV – most anaerobic zones struggle to get -150 mV
- Impossible to achieve with nitrates or DO anywhere
- Most plants were over-mixed with turbulent surfaces that entrained air which prevented deeper anaerobic conditions
- Standard mixing energy 0.6 hp/kcf – need 0.08 hp/kcf (huge saving in energy)
- Too much air entrained in primary effluent
- Too much primary effluent per se which may contain very little VFA thus diluting the content of the anaerobic zone and reducing the anaerobic SRT

ORP IN ANAEROBIC ZONES

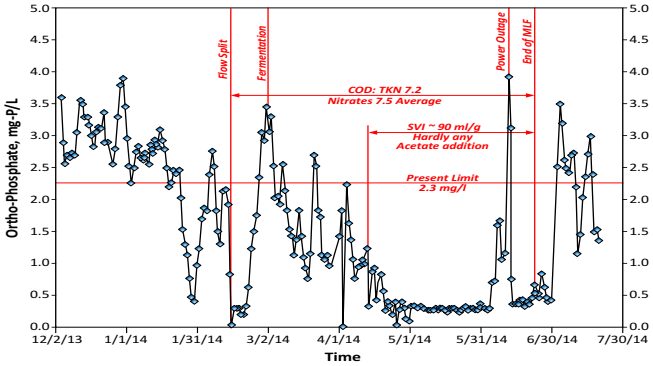


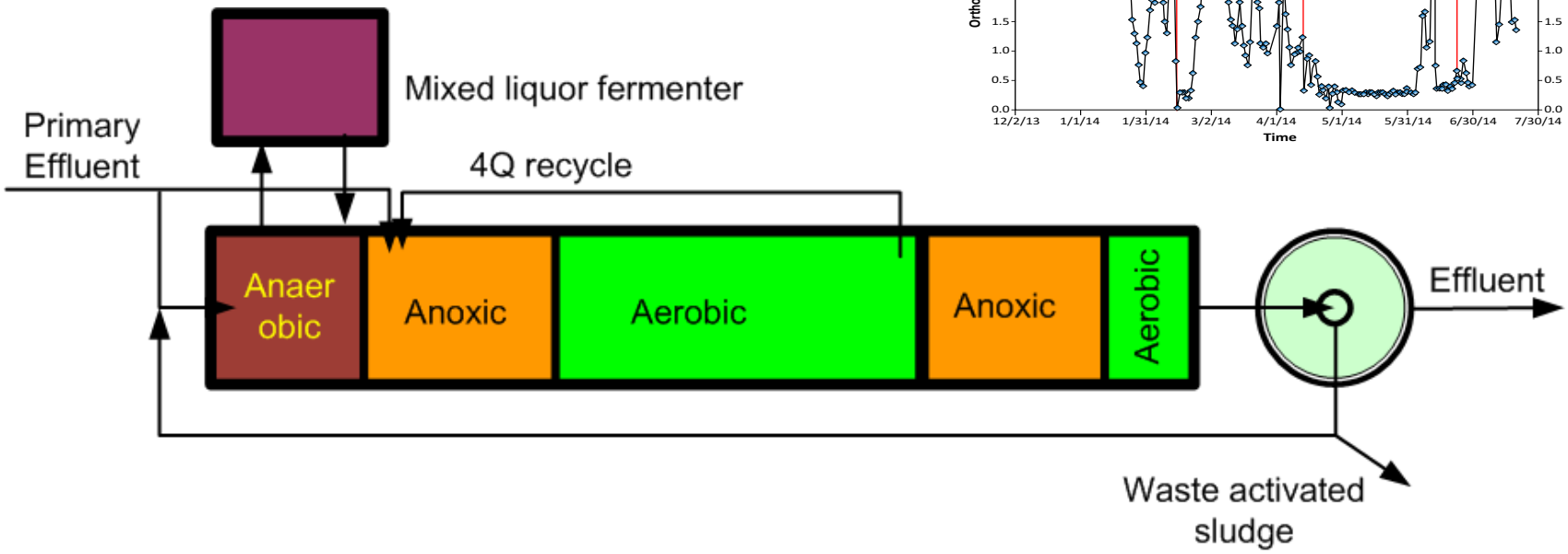
MODIFIED WESTBANK PROCESS



Aim for 1 to 2 day SRT in anaerobic zone (12-18 h with fermentate

WHEN NO PRIMARIES USE MIXED LIQUOR FERMENTER – OLATHE KS, SACRAMENTO CA



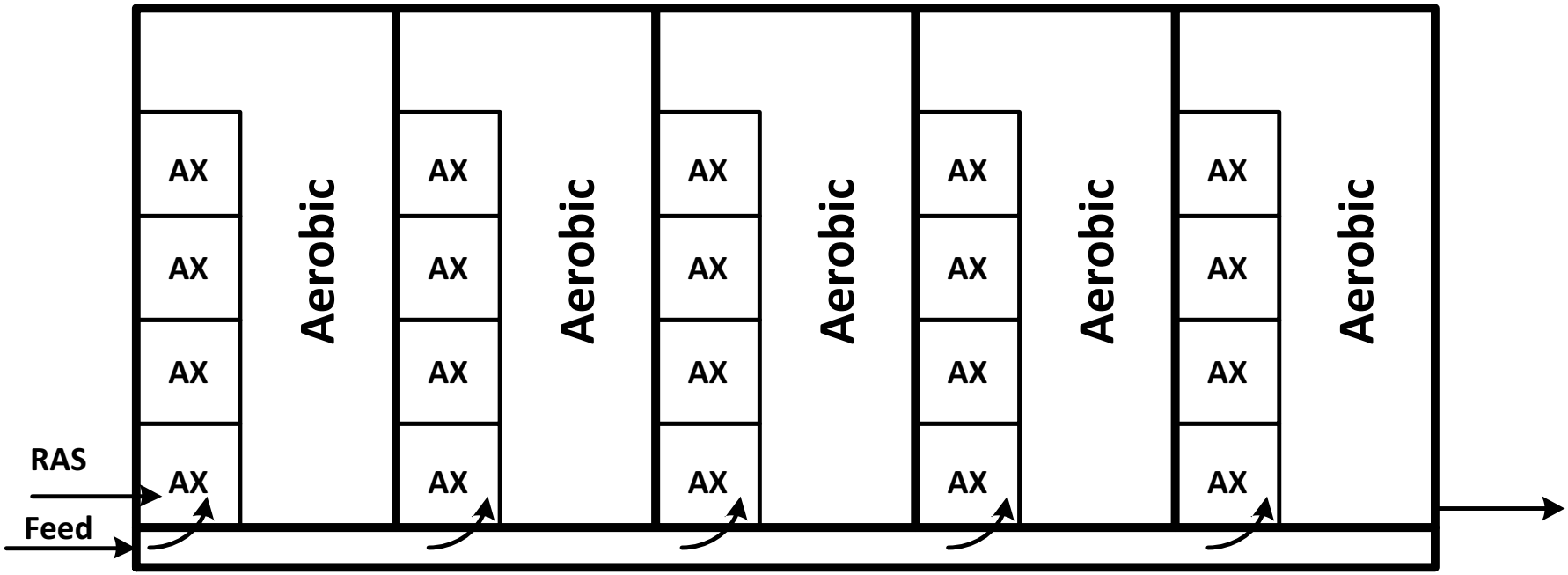


MLF mixed only once per day or less often

Guideline SRT of MLF approximately 2 days

And here I would like to thank Kevin Clark from Pinery Water for showing us the way

LAY-OUT OF CHANGI PLANT - SINGAPORE

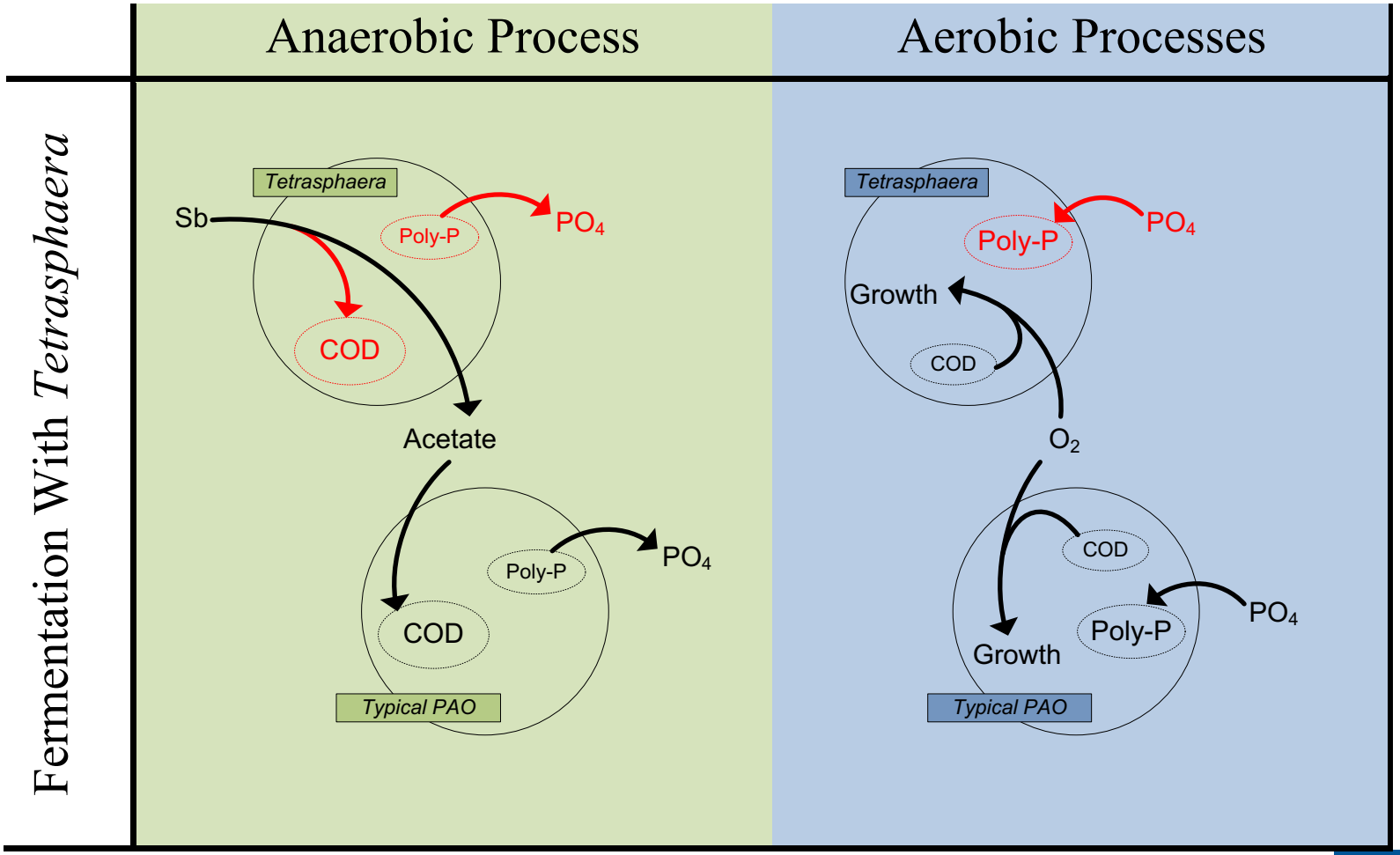


- Step-feed nitrification/denitrification
- Achieve EBPR – Denite PAO
- Presence of Accumulibacter & Tetrasphaera

The Occurrence of Enhanced Biological Phosphorus Removal in a 200,000 m3/day Partial Nitration and Anammox Activated Sludge Process at the Changi Water Reclamation Plant, Singapore – Cao et al, 2016

Process Modeling

TETRASPHAERA IMPACTS MODEL BEHAVIOR



DRAWBACKS OF PARAMETER ADJUSTMENT

- **Coarse parameter adjustment can offer insight into current model shortcomings but; the adjustment of many variables likely results in over adjustment & compensation, calibration is only possible if all relevant mechanisms are incorporated, and it will provide little predictive power when extrapolating beyond specific scenario.**
- **We are working with Northeastern University towards recommendations for better modeling sidestream EBPR as part WERF study**
- **Refer to WWTmod 2016 paper for more information;**

  Rethinking EBPR: What do you do when the model will not fit real-world evidence?

CONCLUSIONS

- Shortcomings of design resulted in selection for limited variety of PAO, mainly those that need a supply of SCVFA
- Deeper anaerobic conditions are needed to cultivate fermenting PAO such as Tetrasphaera
- These organisms can also take up phosphorus under anoxic conditions
- Limit HRT in anaerobic zone by reduced primary effluent discharge and/or reduced RAS flow
- Wastewater characteristics irrelevant
- Modeling for alternative species of fermenting PAOs

Thank you all for coming

DISCUSSIONS

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