OPTIMIZING BPR WITH INLINE FERMENTATION

BRIEF

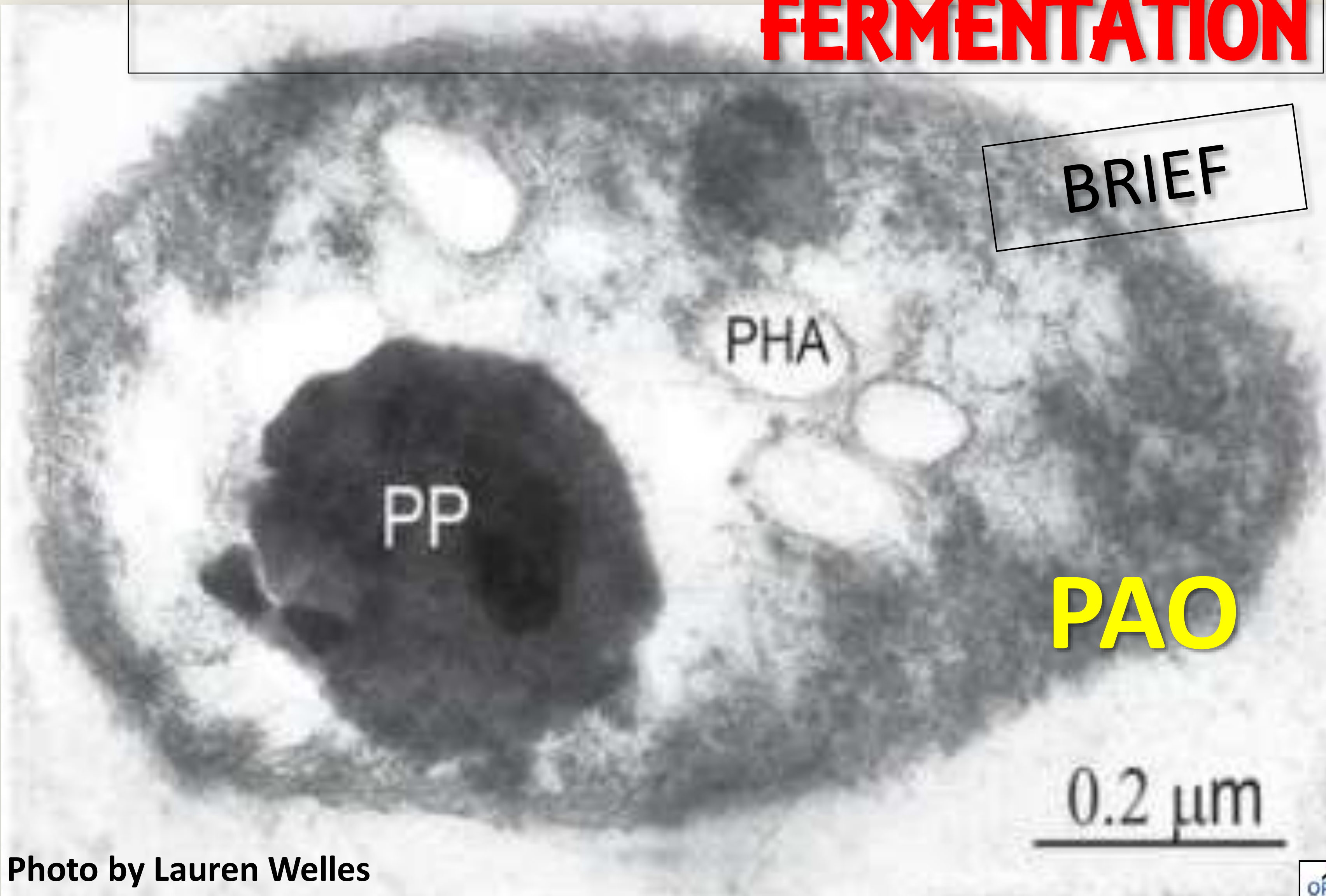
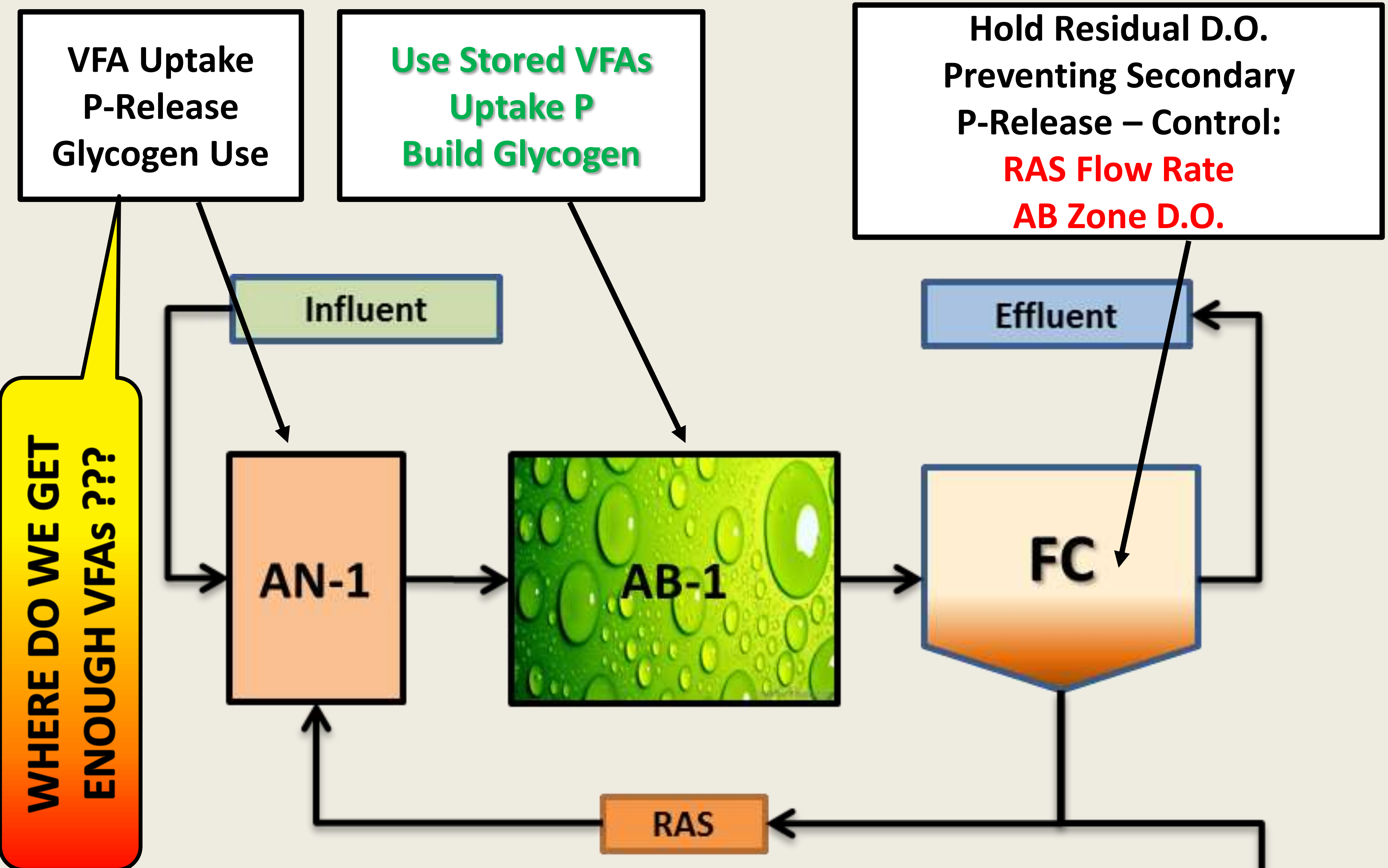


Photo by Lauren Welles



VFA Uptake
P-Release
Glycogen Use
Use Stored VFAs
Uptake P
Build Glycogen
Hold Residual D.O.
Preventing Secondary
P-Release – Control:
RAS Flow Rate
AB Zone D.O.
WHERE DO WE GET
ENOUGH VFAs ???
Influent
Effluent
AN-1
AB-1
FC
RAS
WAS

AO System

This is What We Strive For

Total BOD Demand, lbs./hr.

This is total lbs. BOD to satisfy P & N removal requirements

VS.

Total Available BOD, lbs./hr.

This is total lbs. BOD available in the influent to system plus any supplemental BOD provided

ORP – a Simple Indirect Measurement of Total BOD Demand

A well operating EBPR system needs these two items to match up or equal each other

OP2MYZ LLC

ORP – a Simple Indirect Measurement of Total BOD Demand

LAWS OF ORP

Item	*Increase* Item - what happens to ORP ???	*Decrease* Item - what happens to ORP ???
Influent BOD	↓	↑
RAS Flow	↑	↓
Sludge Age or SRT	↓	↑
Aeration tank D.O. set point	↑	↓

How do we make improvements?

Make this smaller

Total BOD Demand, lbs./hr.

This is total lbs. BOD to satisfy P & N removal requirements

VS.

Make this bigger

Total Available BOD, lbs./hr.

This is total lbs. BOD available in the influent to system plus any supplemental BOD provided

Decrease Side stream

Three Main Choices for Improvement

1-Make the BOD Demand Smaller

2-Increase the Available BOD

3-Or Both, Reduce BOD Demand & Increase Available BOD

Extreme Sidestream Schedule

7 Day

Decrease Side stream IMPACT

BOD:TP Chart	Cent	Cent	Cent	Cent					
	Air off	Decant	Decant	Air on	Air off	Decant	Decant		
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY		Avg/Hr.
12-3am	11	28	11	11	28	28	11	Decant/High %RAS to Inf - High	18.3
3-6am	6	21	6	6	21	21	6	Decant/High %RAS to Inf - High	12.4
6-9am	17	10	10	17	28	14	14	Decant/Cent	15.7
9am-12pm	24	16	16	24	35	21	21	Decant/Cent	22.4
12-3pm	35	22	22	35	35	22	22	Decant	27.6
3-6pm	35	21	21	35	35	21	21	Decant	27.0
6-9pm	35	20	20	35	35	20	20	Decant	26.4
9pm-12am	34	20	20	34	34	20	20	Decant	26.0
								Avg	
Average	24.6	19.8	15.8	24.6	31.4	20.9	16.9	22.0	
% Out	37.5%	25.0%	50.0%	37.5%	0.0%	12.5%	37.5%	28.6%	

How do we make improvements?

Make this smaller

Total BOD Demand, lbs./hr.

This is total lbs. BOD to satisfy P & N removal requirements

VS.

Make this bigger

Total Available BOD, lbs./hr.

This is total lbs. BOD available in the influent to system plus any supplemental BOD provided

Three Main Choices for Improvement

1-Make the BOD Demand Smaller

2-INCREASE THE AVAILABLE BOD

3-Or Both, Reduce BOD Demand & Increase Available BOD

Increasing BOD:

- "Clean" Industrial Waste or QLF
- **Inline Fermentation**
  - MOST COST EFFECTIVE !!!
- Or Combination

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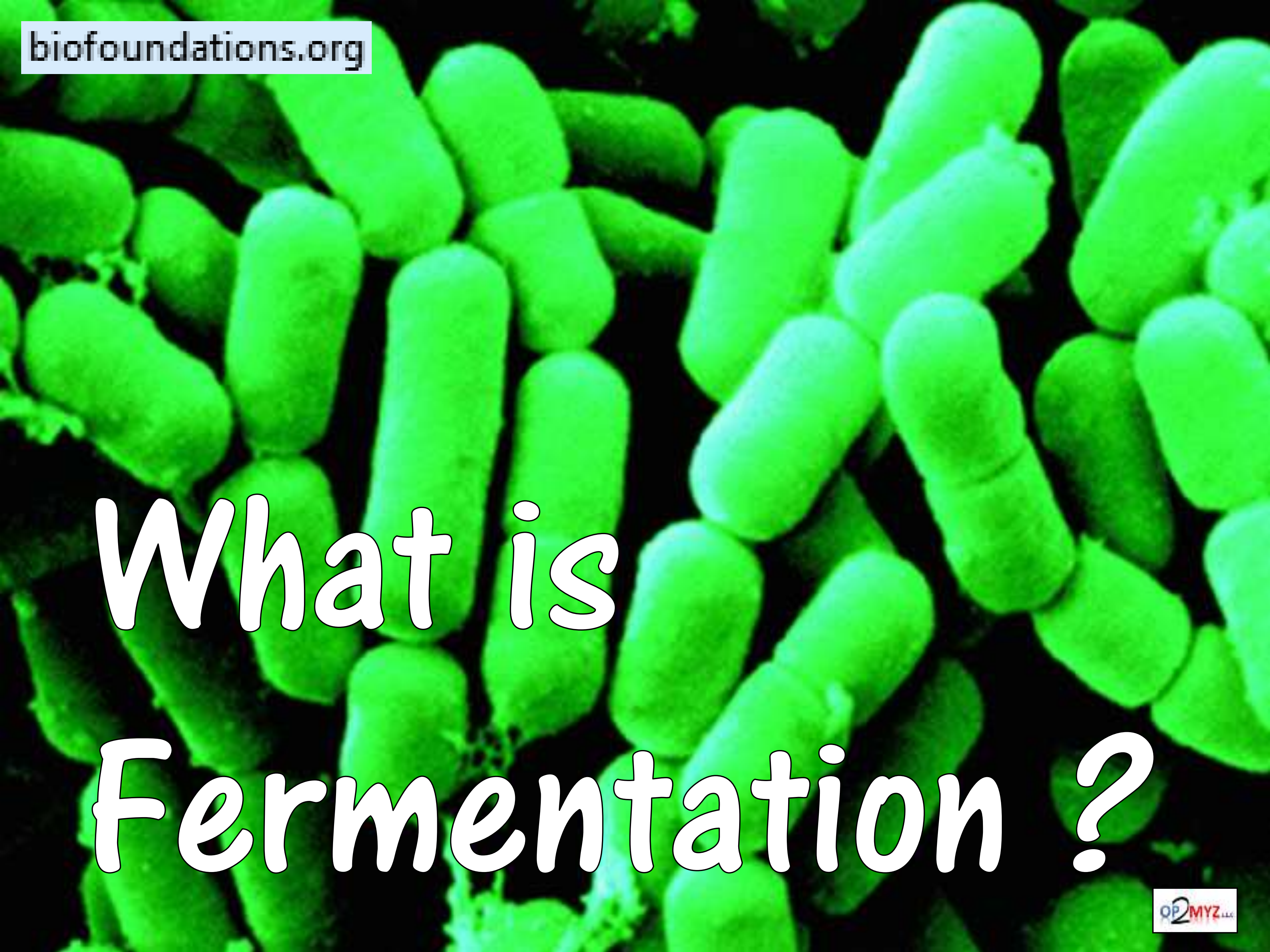
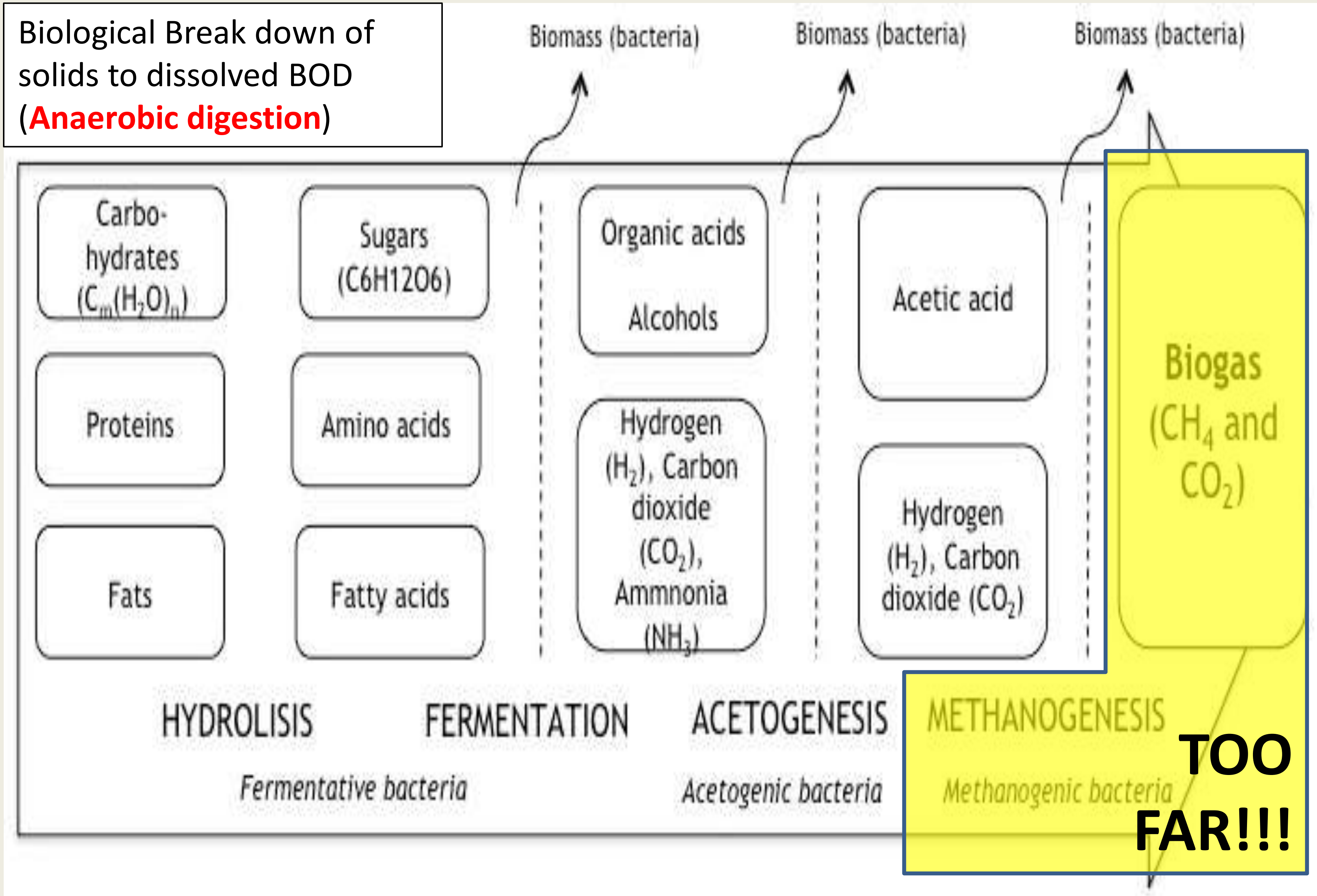
biofoundations.org



What is Fermentation ?

Biological Break down of solids to dissolved BOD (**Anaerobic digestion**)



sswm.info

Its's Anaerobic digestion without METHANOGENSIS

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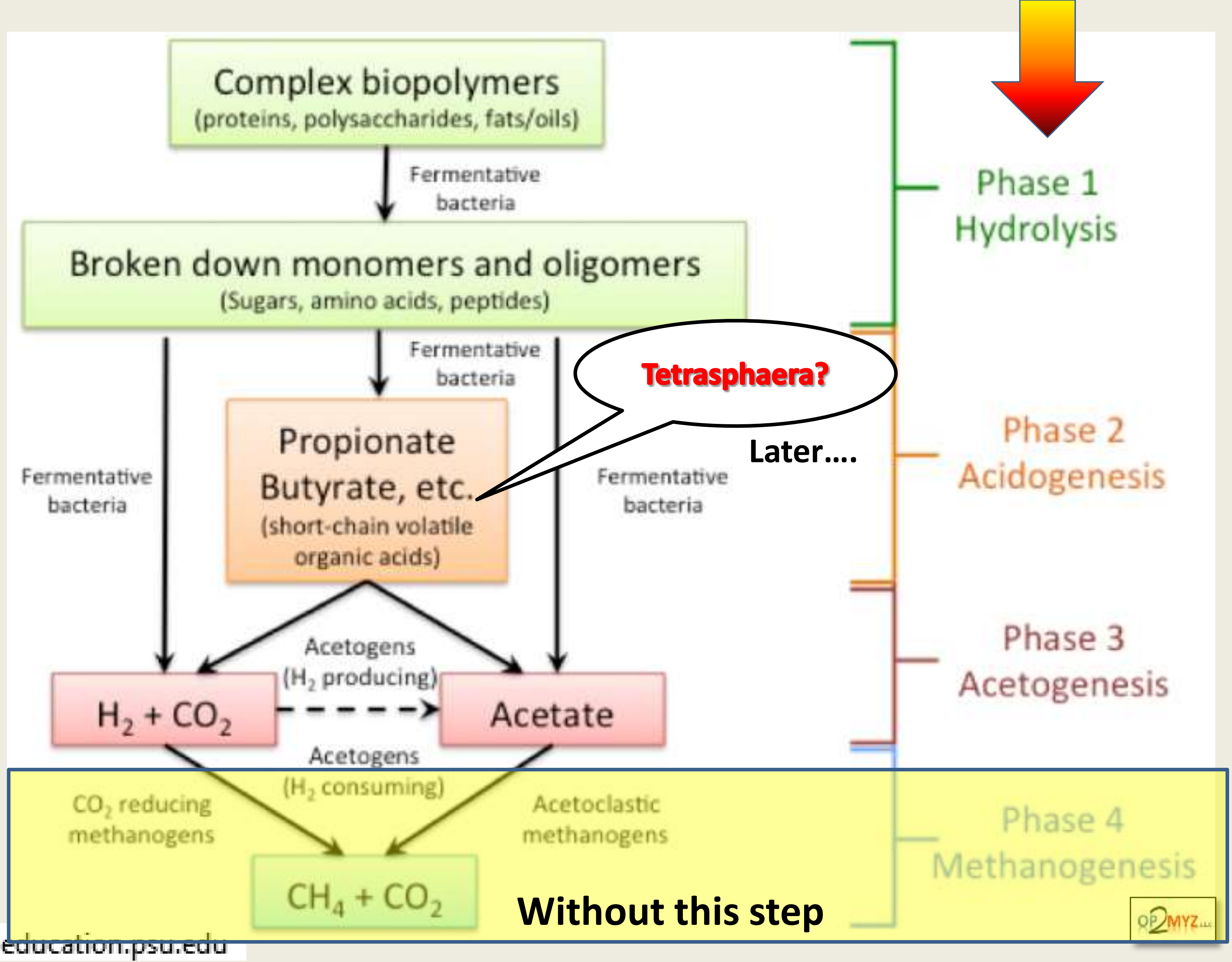
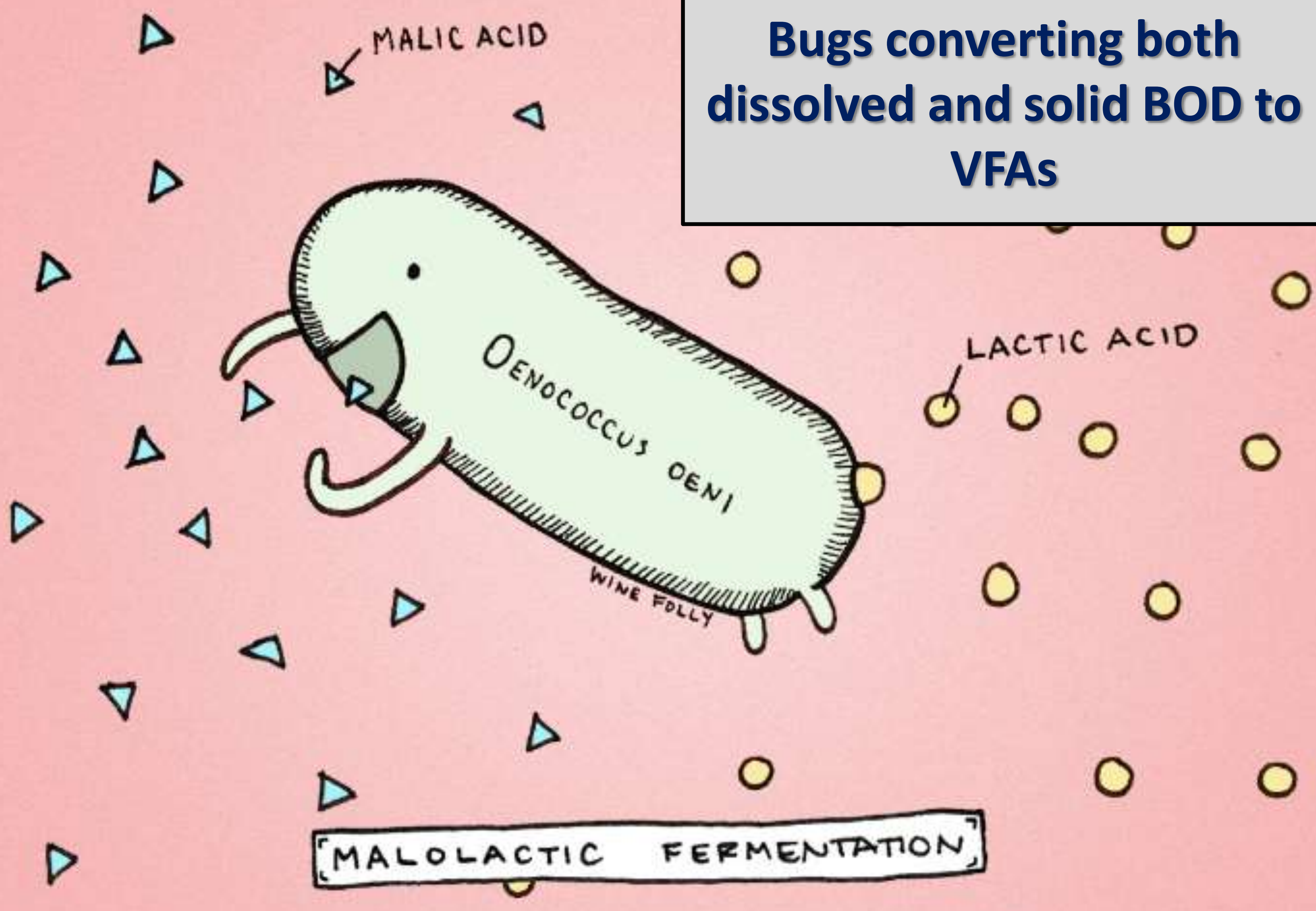


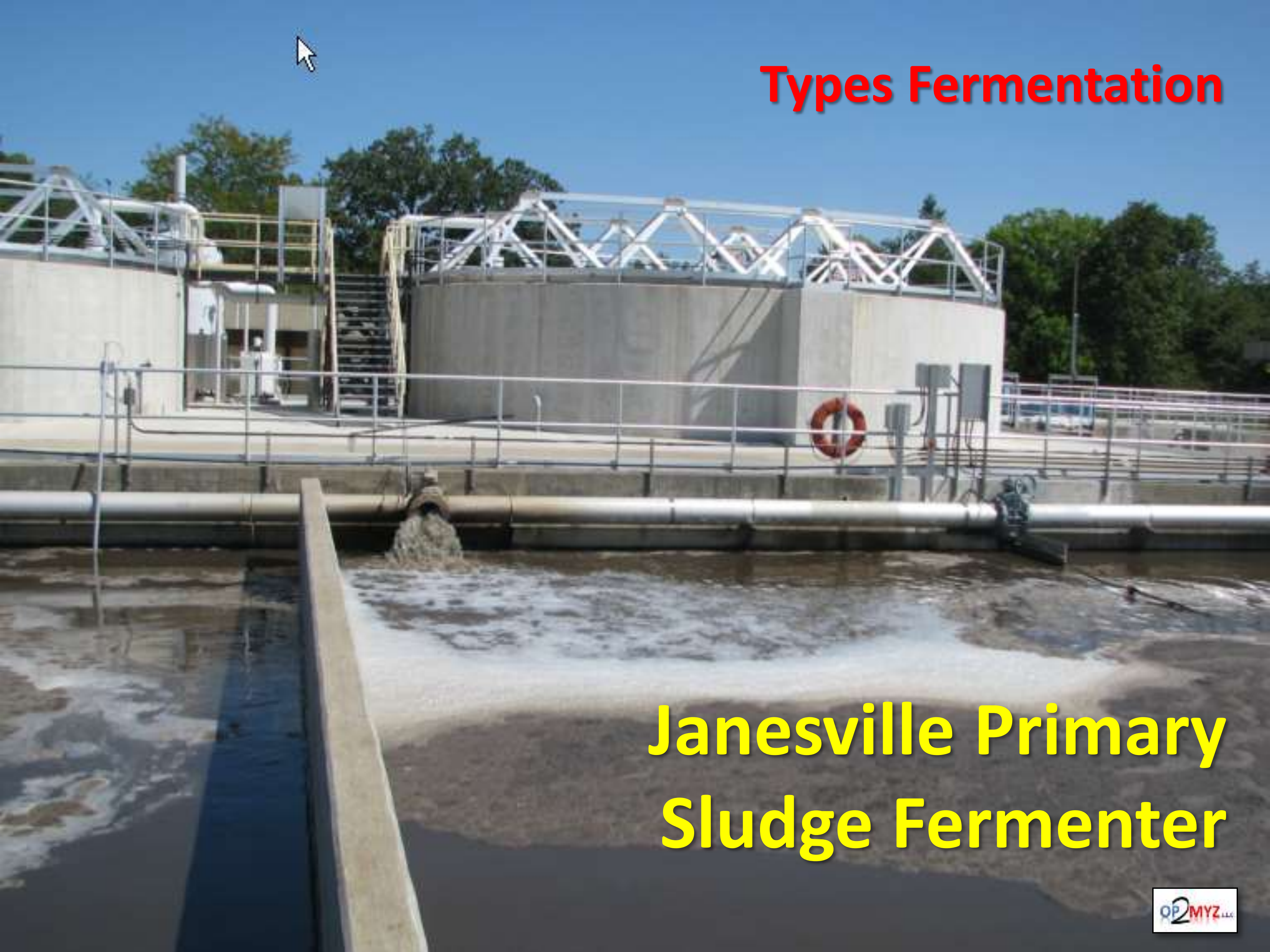
Complex biopolymers
(proteins, polysaccharides, fats/oils)
Fermentative bacteria
Broken down monomers and oligomers
(Sugars, amino acids, peptides)
Fermentative bacteria
Propionate
Butyrate, etc.
(short-chain volatile organic acids)
Fermentative bacteria
Fermentative bacteria
Tetrasphaera?
Later....
Acetogens
(H_2 producing)
$H_2 + CO_2$
Acetate
Acetogens
(H_2 consuming)
CO_2 reducing methanogens
Acetoclastic methanogens
$CH_4 + CO_2$
Phase 1
Hydrolysis
Phase 2
Acidogenesis
Phase 3
Acetogenesis
Phase 4
Methanogenesis
Without this step
e-education.psu.edu

Bugs converting both dissolved and solid BOD to VFAs



Various types of fermentation

winefolly.com


Types Fermentation
Janesville Primary
Sludge Fermenter


INLINE
FERMENTATION
OP2MYZ

Inline Fermentation

WHAT IS IT?

Demo of
ON/OFF mixer in
Anaerobic
converted to
Inline
Fermentation
tank

Lindenhurst

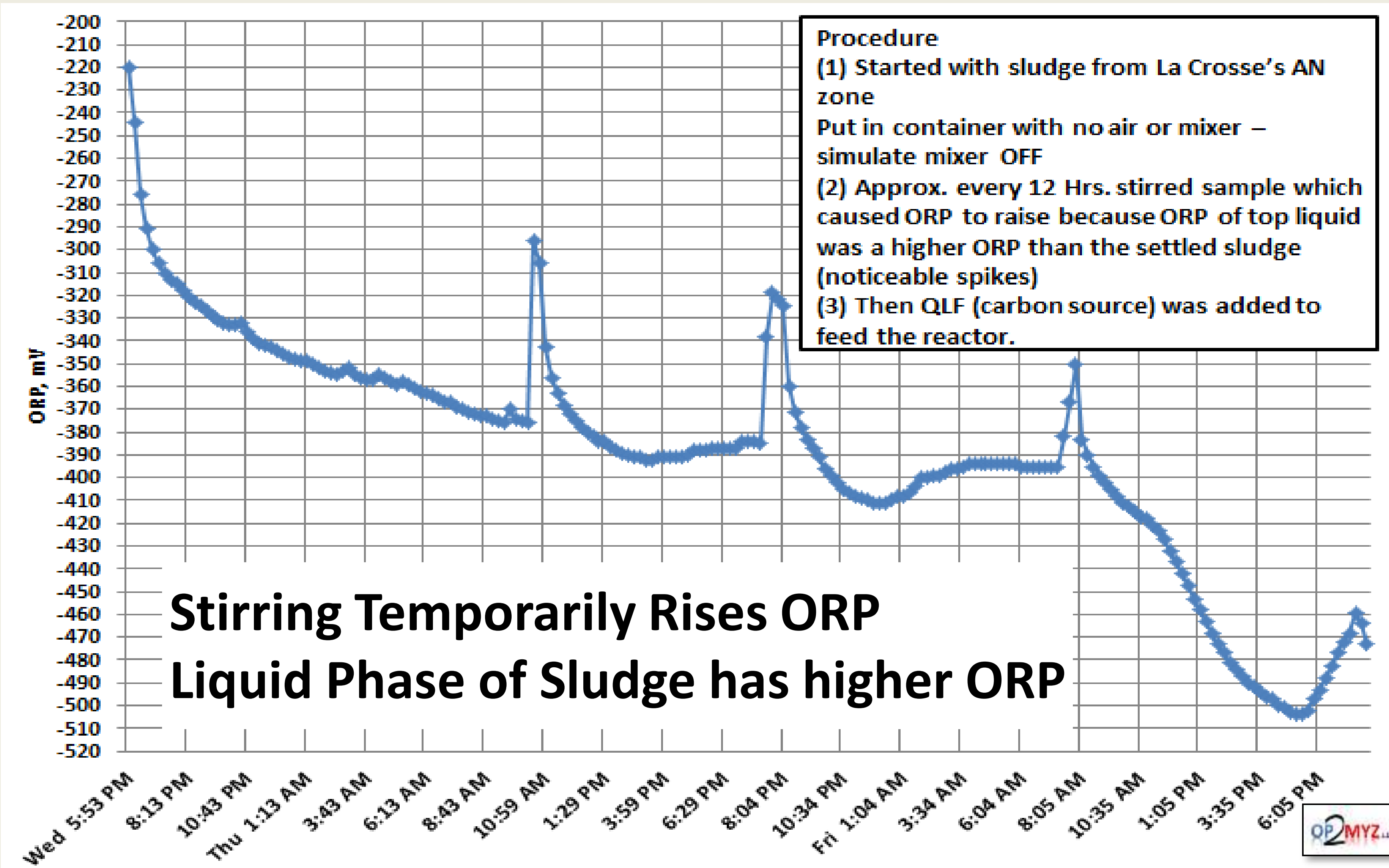
Fermenting

Before the mixer starts up in inline fermentation Menomonie

OP2MYZ LLC


Fermenting
After the mixer starts up in inline fermentation
AFTER

Bench On/Off Mixer AN Zone Supplemental Carbon Addition



Fermentation

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DNAmyWastewater™ (Microbe Detectives™)

Canonical Name (Previous Name)	Fermented.Overflow. [redacted] (% of Total Bacteria)	Mixed.Liquor.[redacted] [redacted](% of Total Bacteria)
Fermenters		
Actinobacteria	8.51%	1.88%
Firmicutes	27.78%	6.56%
Propionivibrio	0.03%	0.58%
Tetrasphaera	0.00%	0.31%
Propionicimonas	0.00%	0.00%
Streptococcus	1.50%	0.22%
Lactococcus	0.07%	0.13%
Phosphorus		
Defluviicoccus (GAO)	0.00%	0.00%
Dechloromonas	0.00%	0.00%
Accumulibacter - PAO	0.00%	0.00%
PAO related p__Proteobacteria;c__Betaproteobacteria;o__Rhodocyclales;f__Rhodocyclaceae	0.11%	5.91%
Tetrasphaera	0.00%	0.31%

Basic Inline Fermentation Principles

- You are Building a Pile – like a compost pile
- So **YES** you need to turn it periodically
  - ON/OFF cycle becomes your control point for the fermenter
  - More OFF time/more fermentation & reverse
- Each EBPR is and will be unique
  - ON/OFF frequency
  - Quality of PILE – see Antioch Examples
- Examples - - - - -

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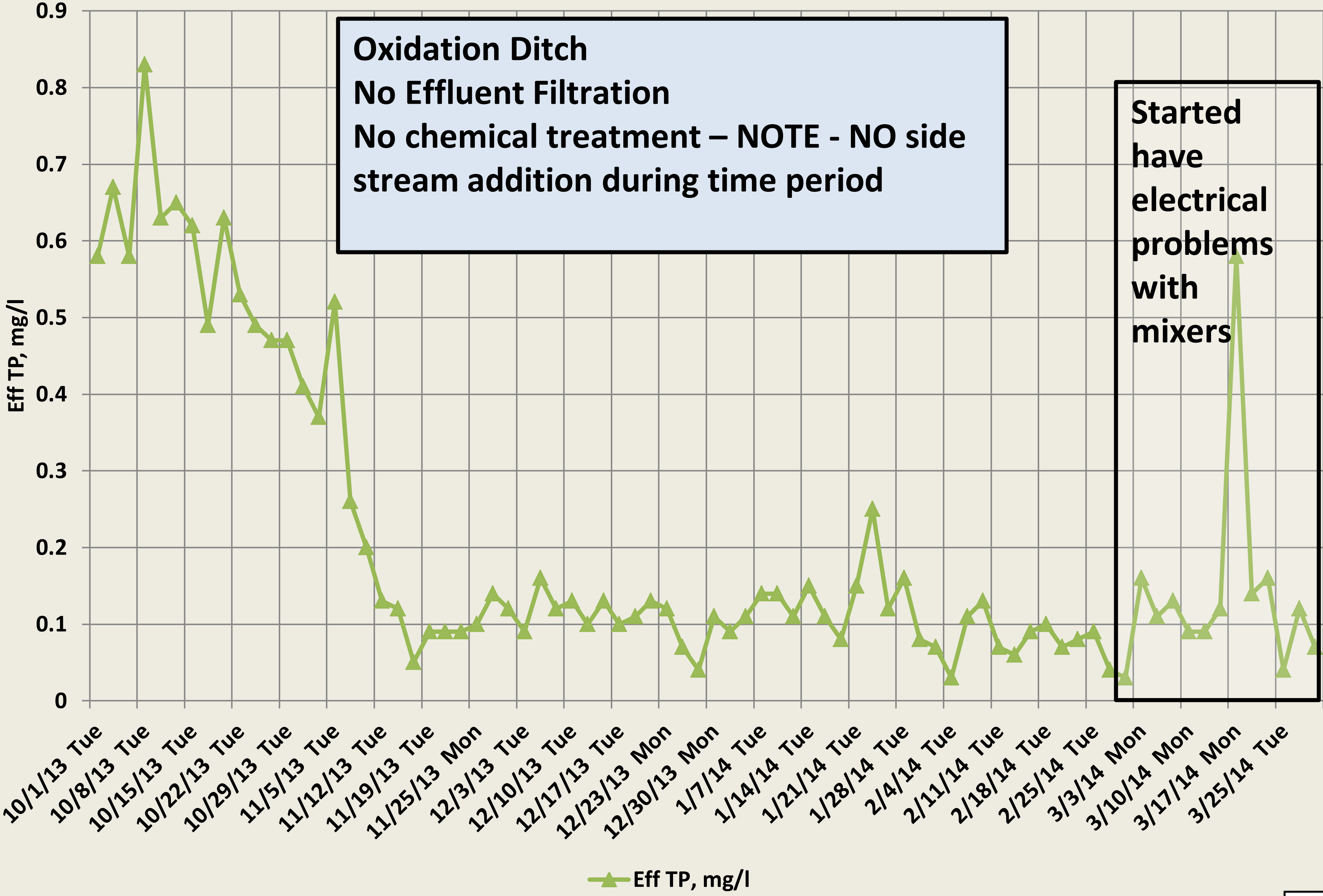
Lake County Inline Fermentation

One of their fermenting zones ON/OFF mixers


Dodgeville
Inline Fermentation

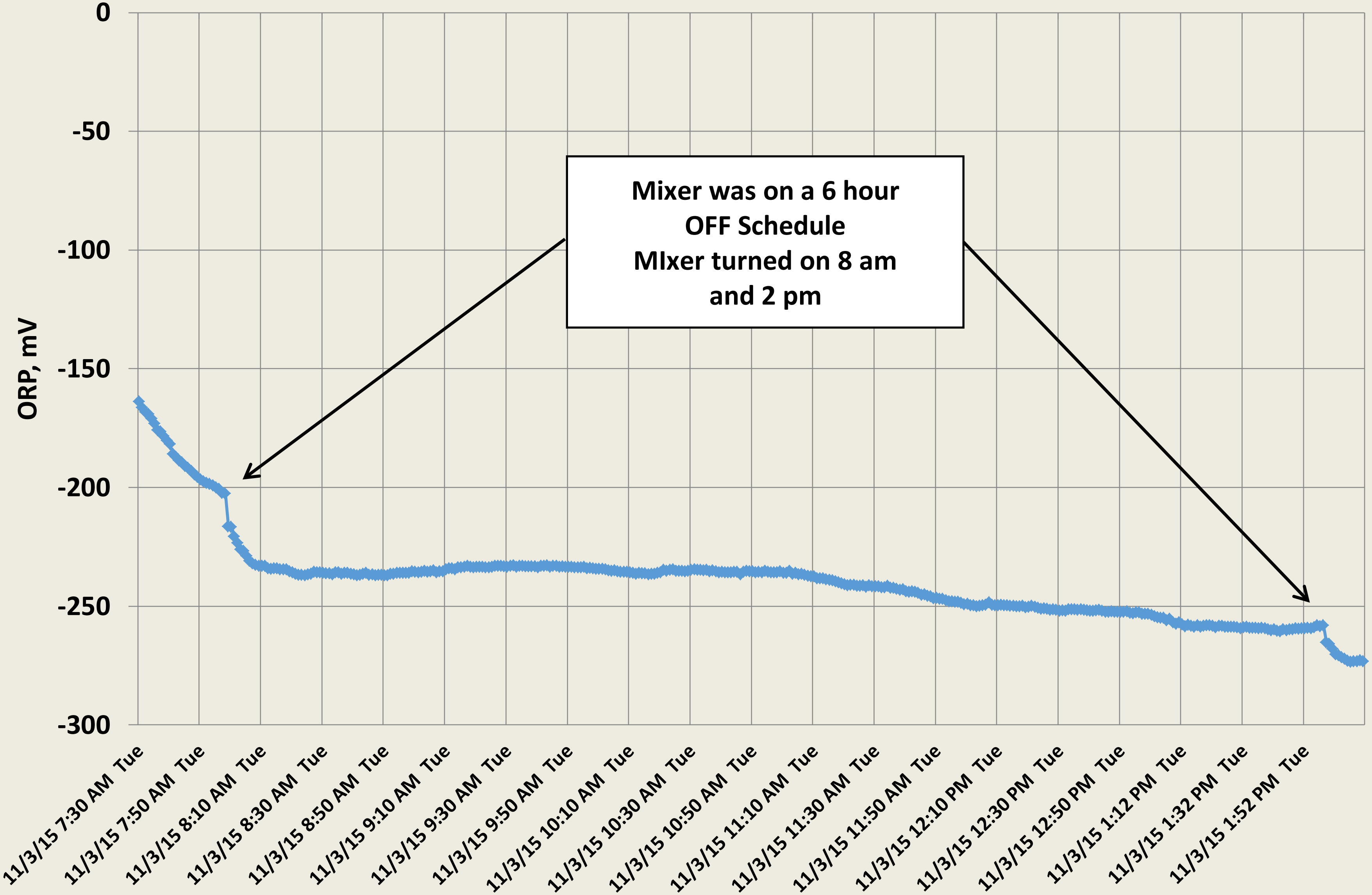
Dodgeville- On/Off Mixer Trial



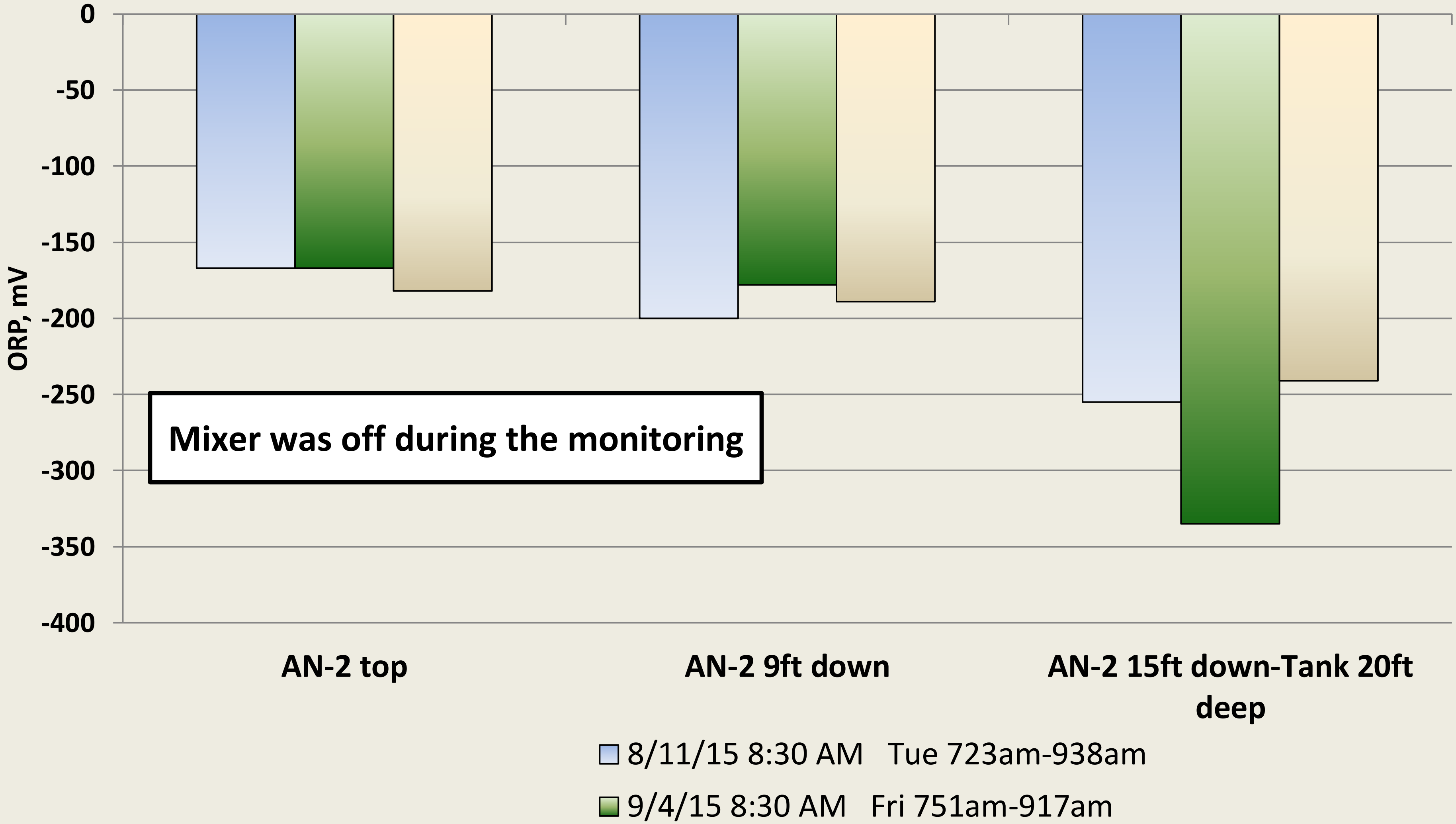
In AN Zone With Inline Fermentation

What Happens to ORP When the Mixers Turns ON

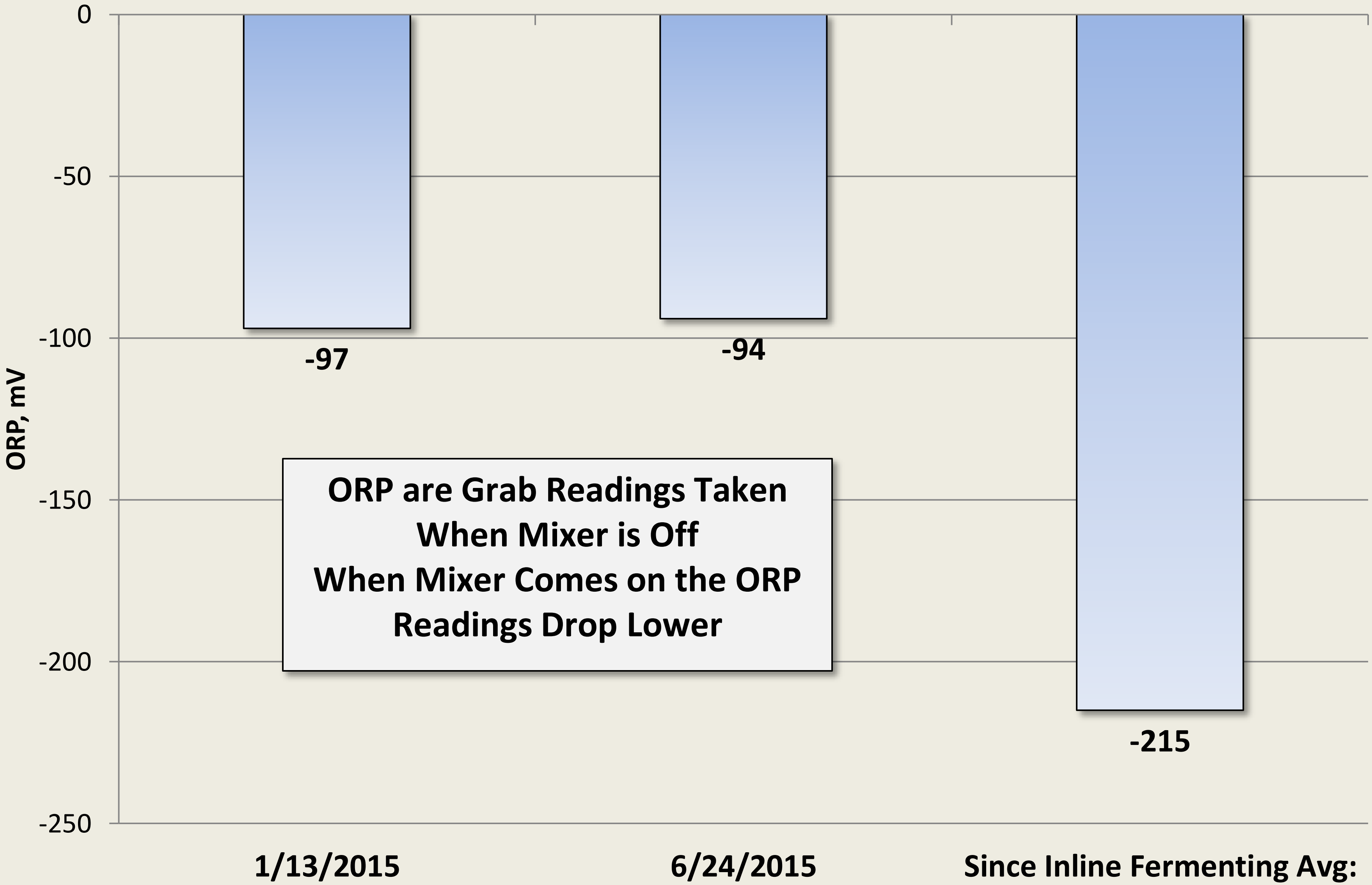
Document ORP Change When Mixer Turns ON in AN-2 -- 11-3-15



Menomonie Inline Fermentation Survey of ORP at Different Depths



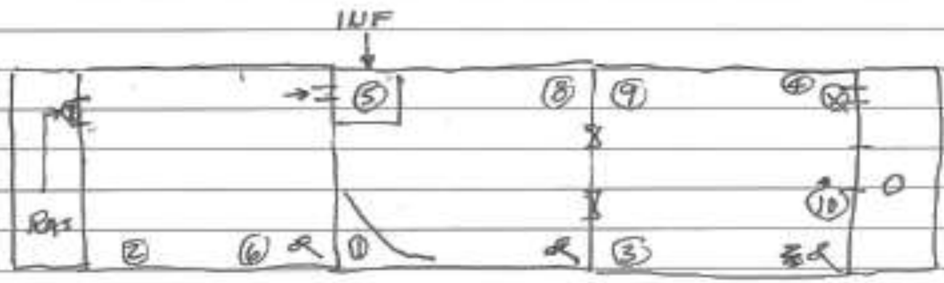
Lindenhurst Inline Fermentation - AN-4 ORP, mV



Eleva-Strum

ORP Survey of Fermenting AN Zone

5-8-15 ELEVA - STRUM



① 830AM PILE 1-2 FT. (ORP - AS [illegible] AS -460) ② NO PILE IN PRE-AN ③ NO PILE IN AN-2 ④ BOTTOM VALVE OPEN NO OVER

910 AM INF ELEVA - 278
STRUM - 296

MIXERS SET AT 30 Hz ?

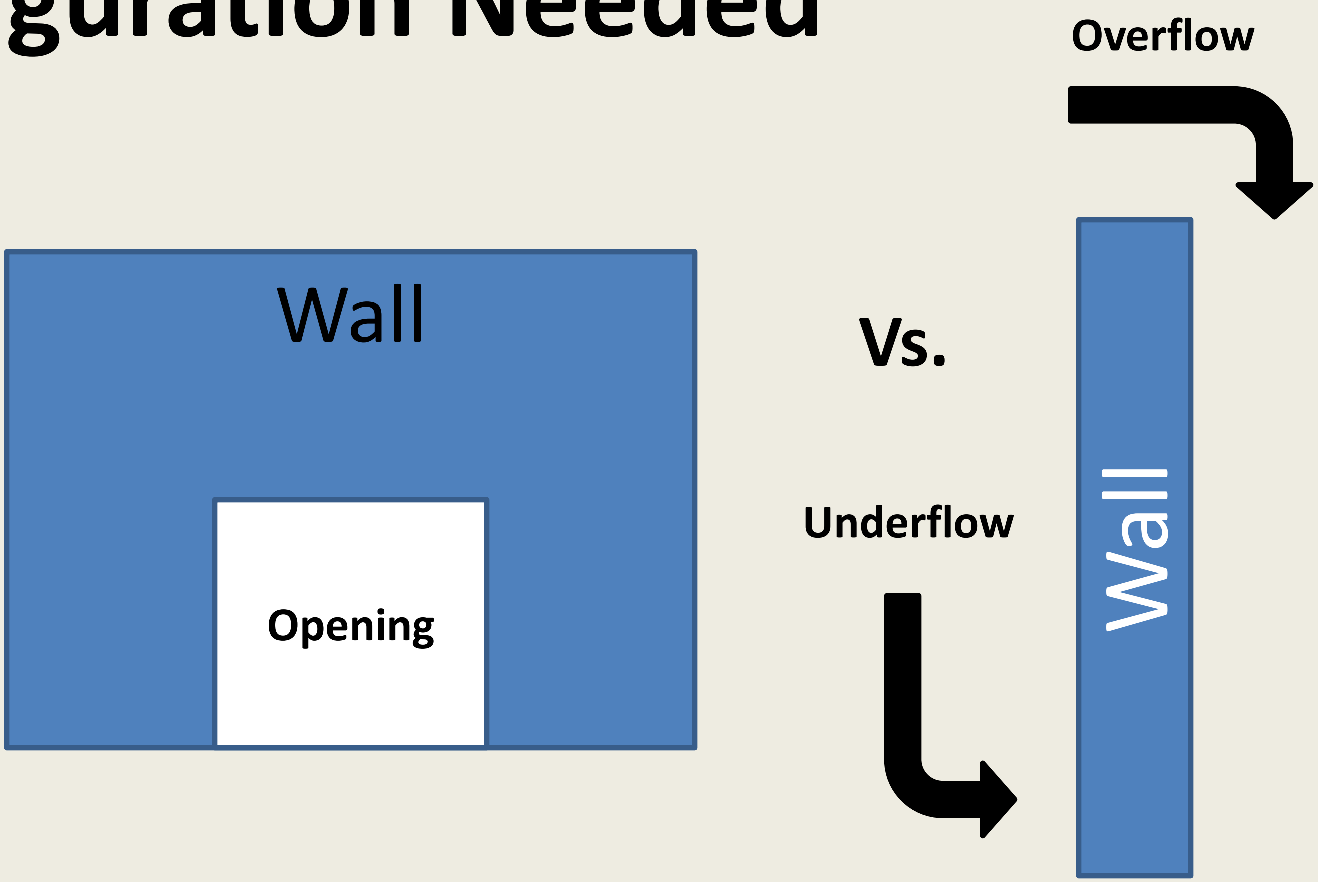
930 AM	RAS ⑦	-222	
945 AM	PREP ⑥	-241	
950 AM	①	-278	3 FT
1005 AM	①	-257	BOTTOM 9-10 FT
1015 AM	⑤	-265	~5 FT
1025 AM	⑧	-290	~3 FT
1035 AM	⑧	-293	BOTTOM 9-10 FT
1045 AM	⑨	-290	~3 FT
1055 AM	⑨	-286	BOTTOM 9-10 FT
1105 AM	④	-293	~3 FT
1110 AM	④	-383	BOTTOM 9-10 FT
1130 AM	③	-282	~3 FT
1136 AM	③	-262	BOTTOM 9-10 FT
1139 AM	⑩	-304	~3 FT
1149 AM	⑩	-307	BOTTOM
~~1155 AM~~	~~⑩~~	~~-[illegible]~~	~~~3 FT~~
1205 PM	⑩	-288	BOTTOM
1218	①	-266	BOTTOM MIXER ON
1228	①	-273	" " OFF
1238	①	-277	"

AN-1 AVG — -277
AN-2 AVG —
PRE-AN — -241
RAS -222

- MAKE FLOW THROUGH AN ZONES - CHANGE ON MAY 18th
- → MAKE IT OVER FLOW VS UNDER FLOW

		ON/HR
MIXERS	AN-1	10 MIN
???	AN-2	30 MIN

Special Inline Fermenter Configuration Needed



ELEVA-STRUM --- EXAMPLE


Antioch
OP2MYZ LLC

ONE STRAIGHT FORWARD METHOD FOR TRACKING AND CONTROL OF INLINE FERMENTATION

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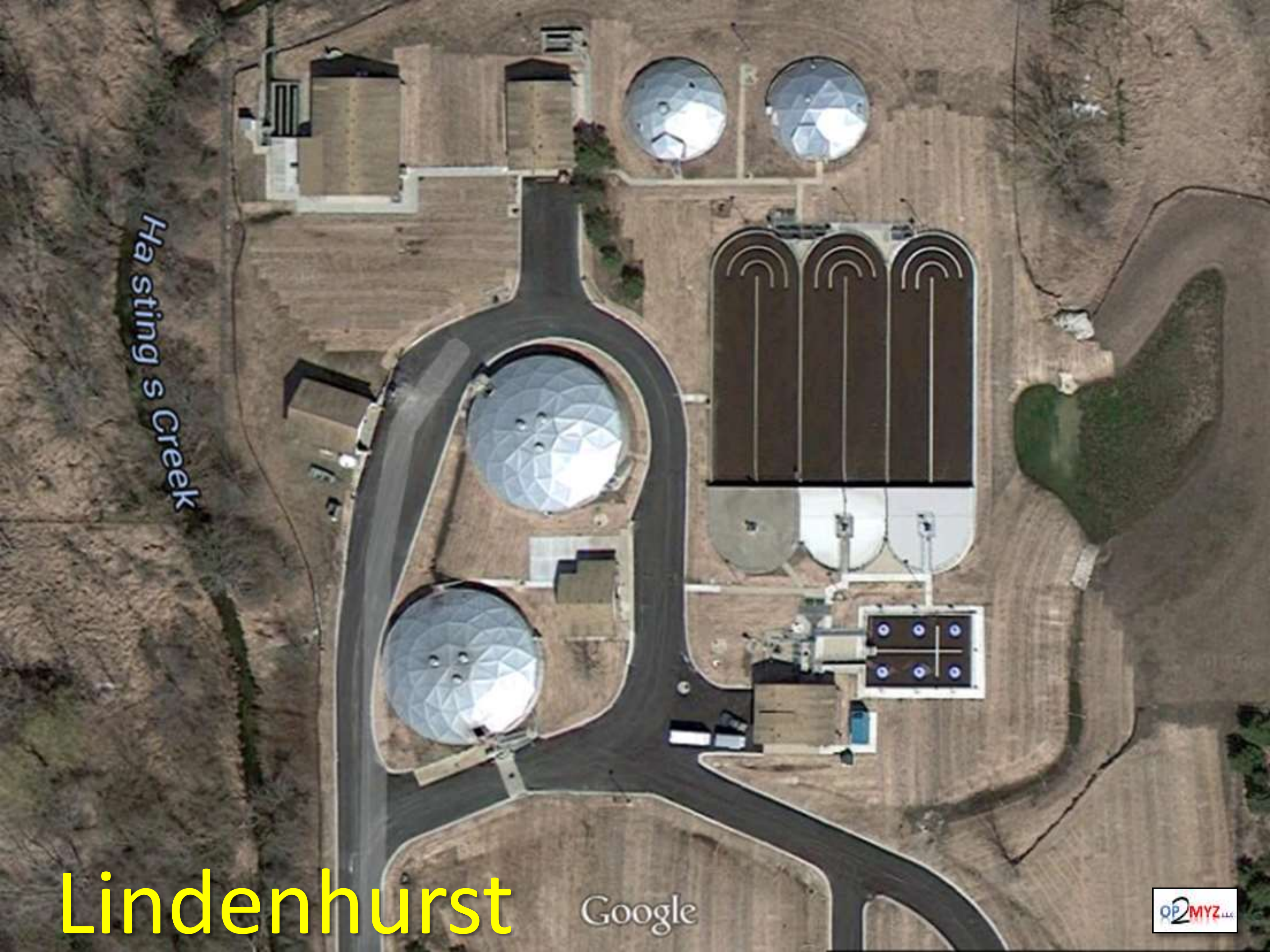
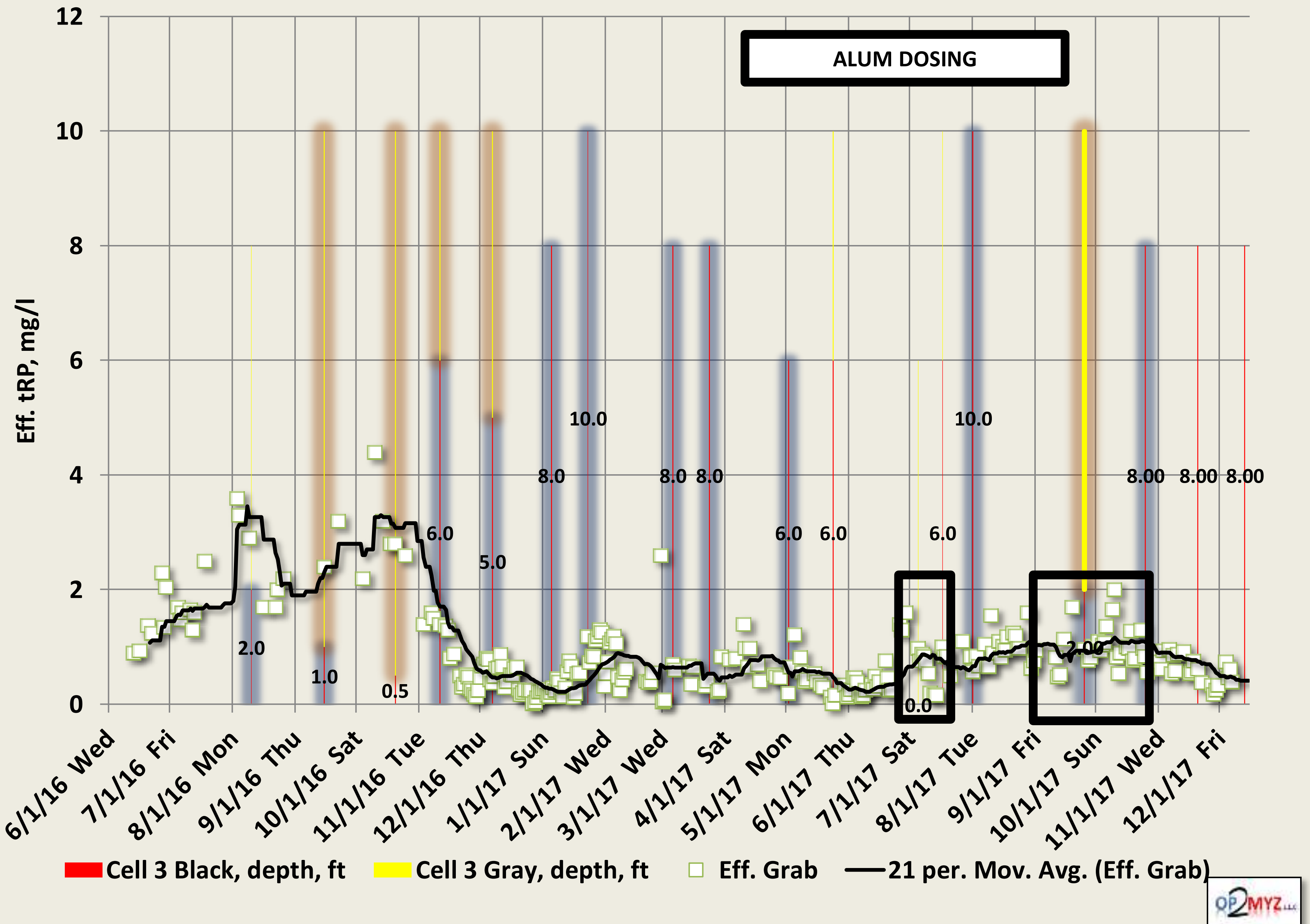

Ha sting s Creek
Google
Lindenhurst

Inline Fermenting AN Zone Mixer ON/OFF Log

	BNR Tank Mixers								
	Cell #2			Cell #3				Cell #6	
Date	Blanket - 16ft. Deep	FF, hrs.	ON, min.	Blanket - 16ft. Deep	Black Sludge, ft	OFF, hrs.	ON, min.	OFF, hrs.	ON, min.
1/22/16 Fri		6	1.00			6	1.00	1	120
3/24/16 Thu		7	0.43			7	0.72	1	120
4/28/16 Thu	2.0	6	0.58	8.0		6	0.92	1	120
5/18/16 Wed	2.0	6	0.58	8.0		6	0.92	1	120
6/7/16 Tue		6	0.58			5	1.08	1	120
7/7/16 Thu		6	0.58			4	1.50	3.7	66
7/18/16 Mon		6	0.58	10.0		4	1.50	3.7	66
8/10/16 Wed	4.0	6	0.58	8.0		4	1.50	3.7	66
8/25/16 Thu		6	0.58			4	1.50	3.7	66
9/15/16 Thu		5	1.00			4	2.00	3.7	66
9/15/16 Thu	3.0	5	1.00	10.0		4	2.00	3.7	66
10/10/16 Mon		5	1.00			4	2.00	3.7	66
10/20/16 Thu	4.0	5	1.00	10.0	0.5	4	2.00	3.7	66
10/24/16 Mon		8	0.41	10.0	1.0	8	0.41	3.7	66
11/11/16 Fri	2.0	8	0.41	10.0	6.0	8	0.75	3.7	66
11/15/16 Tue		8	0.41			8	0.75	3.7	66
11/16/16 Wed		8	0.41			8	0.75	3.7	66
11/22/16 Tue		8	0.41			8	0.75	3.7	66
11/29/16 Tue		8	0.41			8	0.75	3.7	66
12/7/16 Wed	3.0	8	0.41	10.0	5.0	8	0.75	3.7	66
1/5/17 Thu	2.0	8	0.41	8.0	8.0	8	0.75	3.7	66

Lindenhurst Log



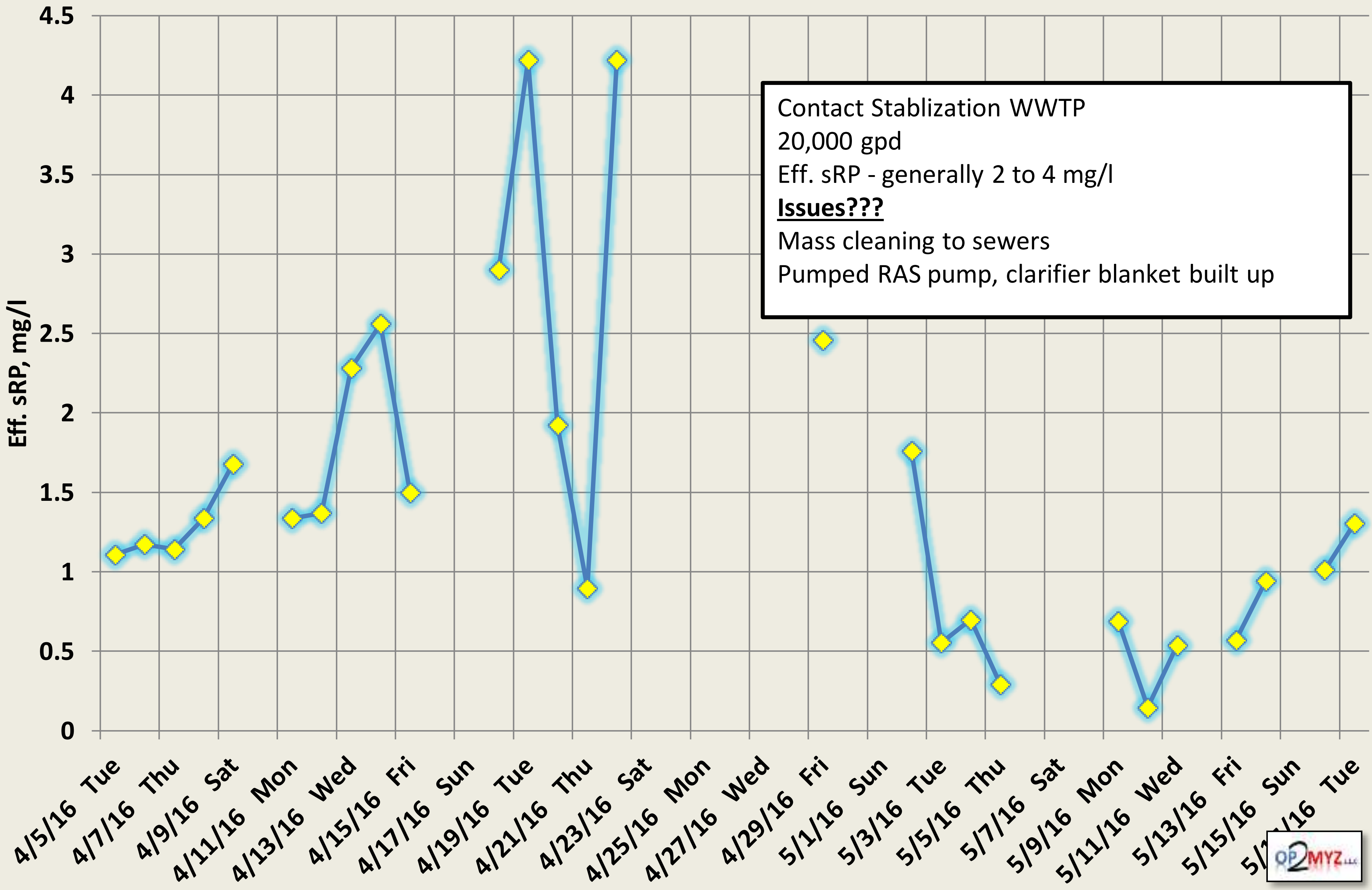
ALUM DOSING
Eff. tRP, mg/l
0
2
4
6
8
10
12
2.0
1.0
0.5
6.0
5.0
8.0
10.0
8.0
8.0
6.0
6.0
0.0
6.0
10.0
2.00
8.00
8.00
8.00
6/1/16 Wed
7/1/16 Fri
8/1/16 Mon
9/1/16 Thu
10/1/16 Sat
11/1/16 Tue
12/1/16 Thu
1/1/17 Sun
2/1/17 Wed
3/1/17 Wed
4/1/17 Sat
5/1/17 Mon
6/1/17 Thu
7/1/17 Sat
8/1/17 Tue
9/1/17 Fri
10/1/17 Sun
11/1/17 Wed
12/1/17 Fri
Cell 3 Black, depth, ft
Cell 3 Gray, depth, ft
Eff. Grab
21 per. Mov. Avg. (Eff. Grab)

Plant Fermenting in Some Fashion

- – Menomonee
- – LaCrosse
- – Lake County
- – Lindenhurst
- – Medford
- – Eleva-Strum
- – Genoa
- – Viroqua
- – Slinger
- – Fond due Lac
- – Linden
- – Green Bay
- – Antioch
- – Marshfield
- – Reedsburg
- – Other??

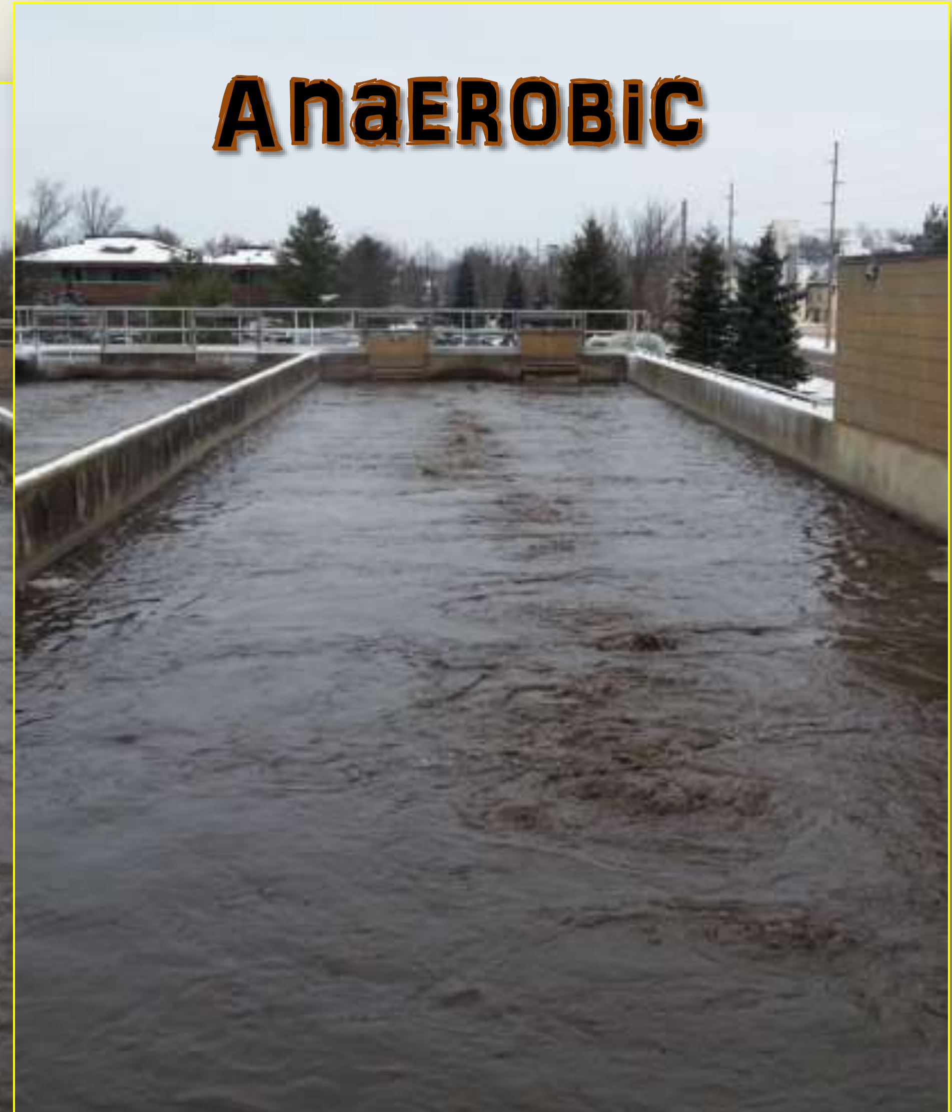

Accidental Fermentation
Genoa

Genoa WWTP Eff. sRP, mg/l



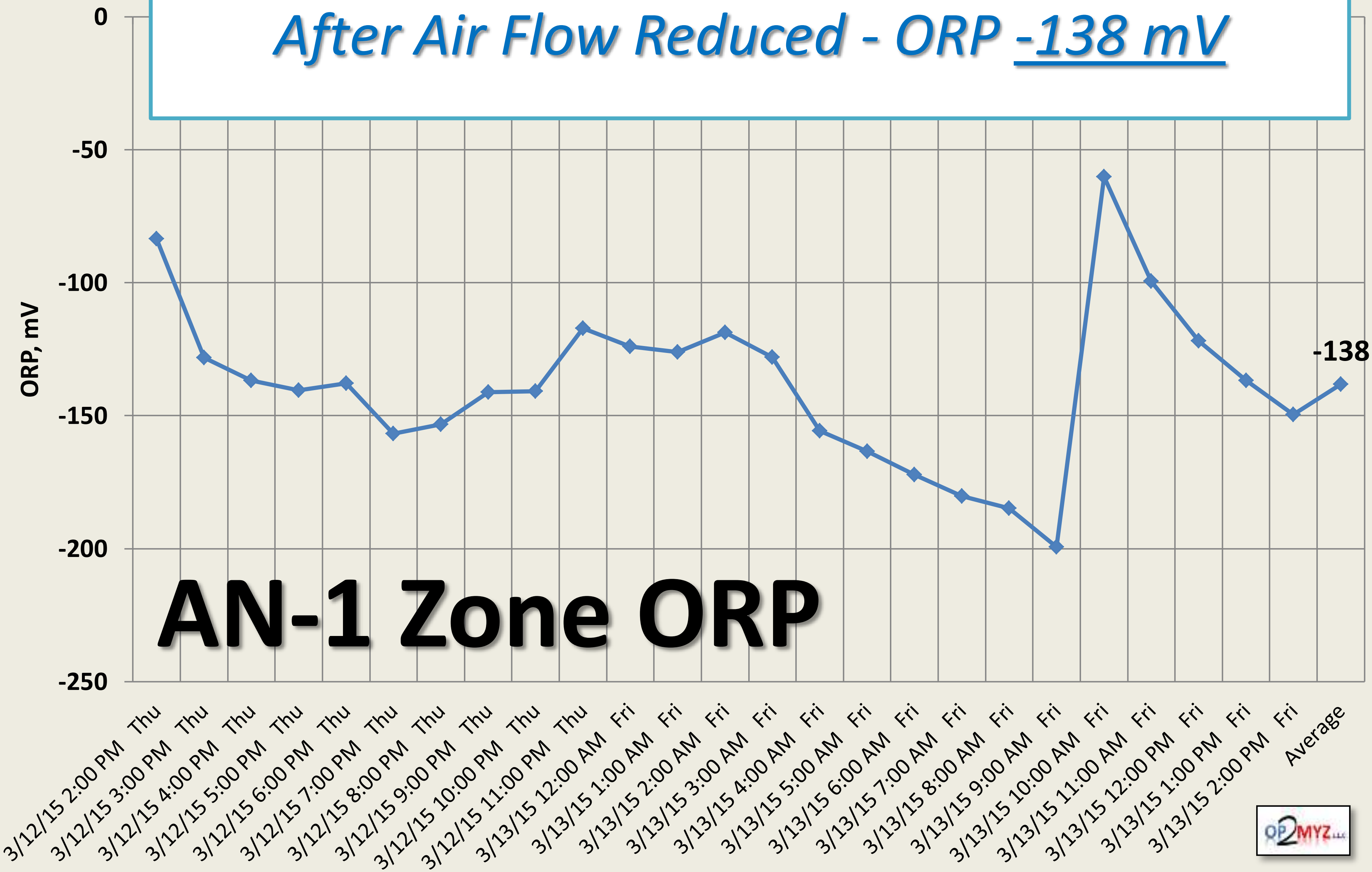

Medford
S Whelen Ave


AEROBIC


AnaEROBIC

Before Reducing Air Flow - ORP - 5 mV

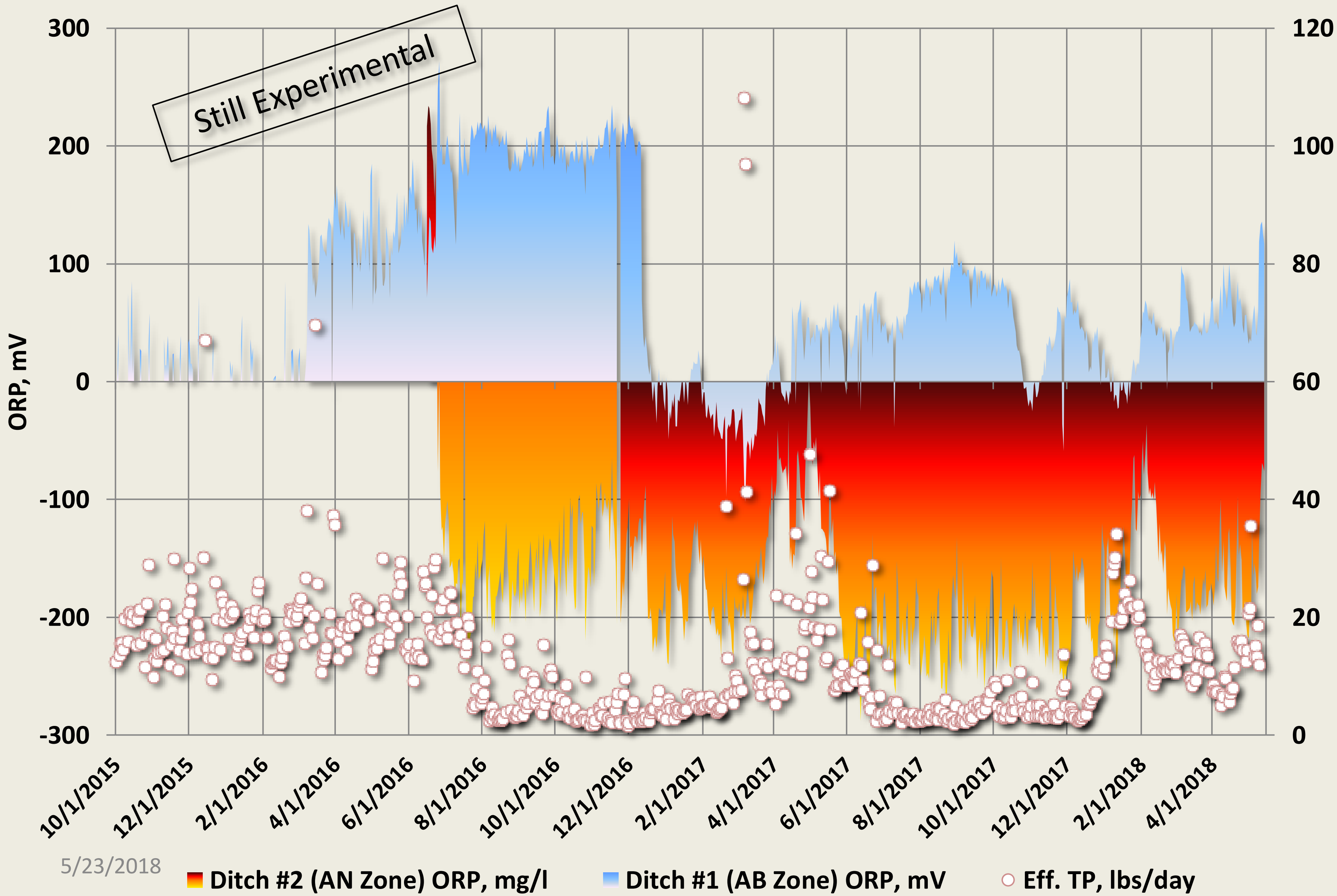
After Air Flow Reduced - ORP -138 mV



Marshfield

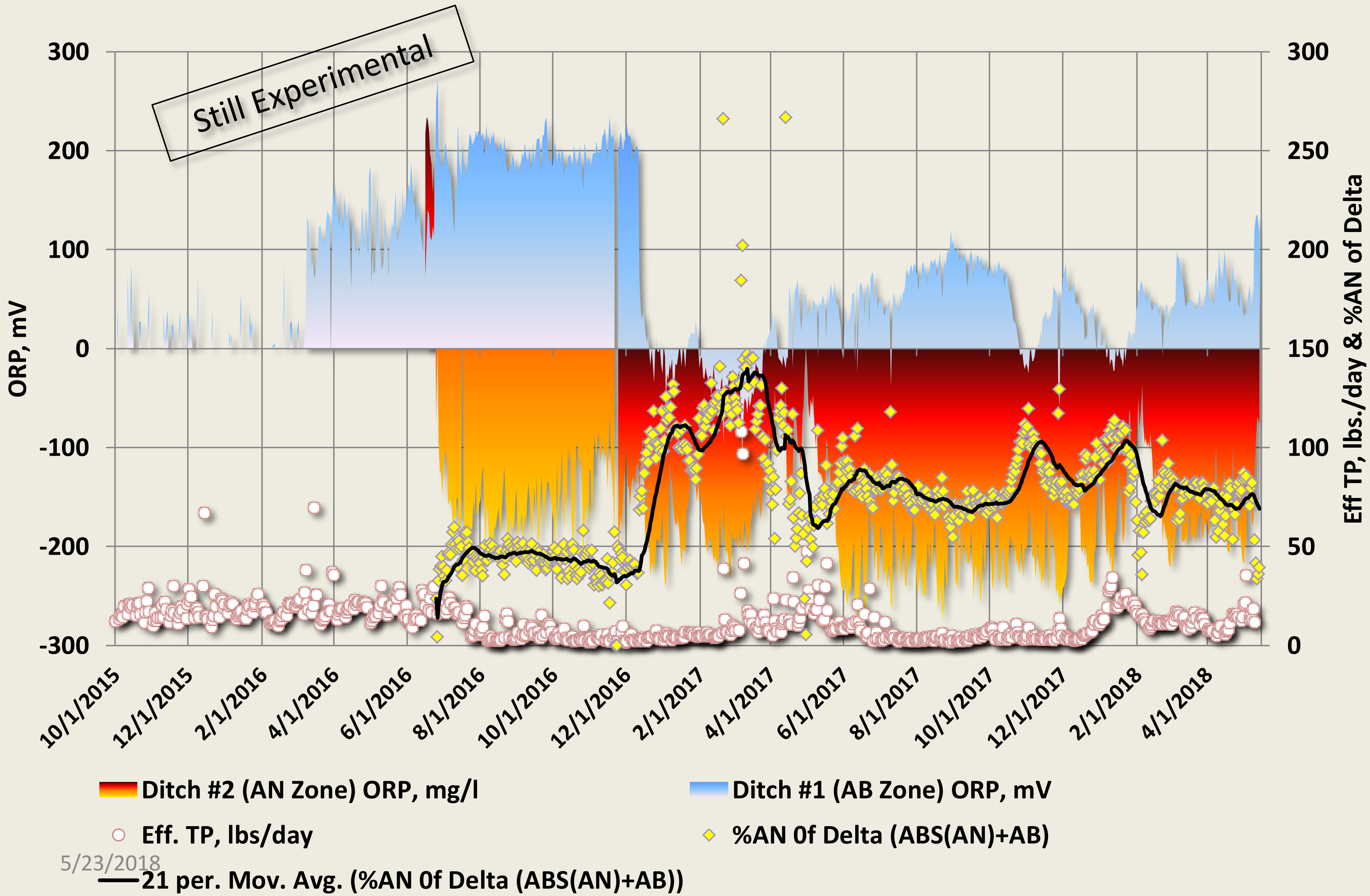
Will show ORP impact o n Eff. TSS too

ORP – AN & AB Zone – Eff TP



Will show ORP impact o n Eff. TSS too

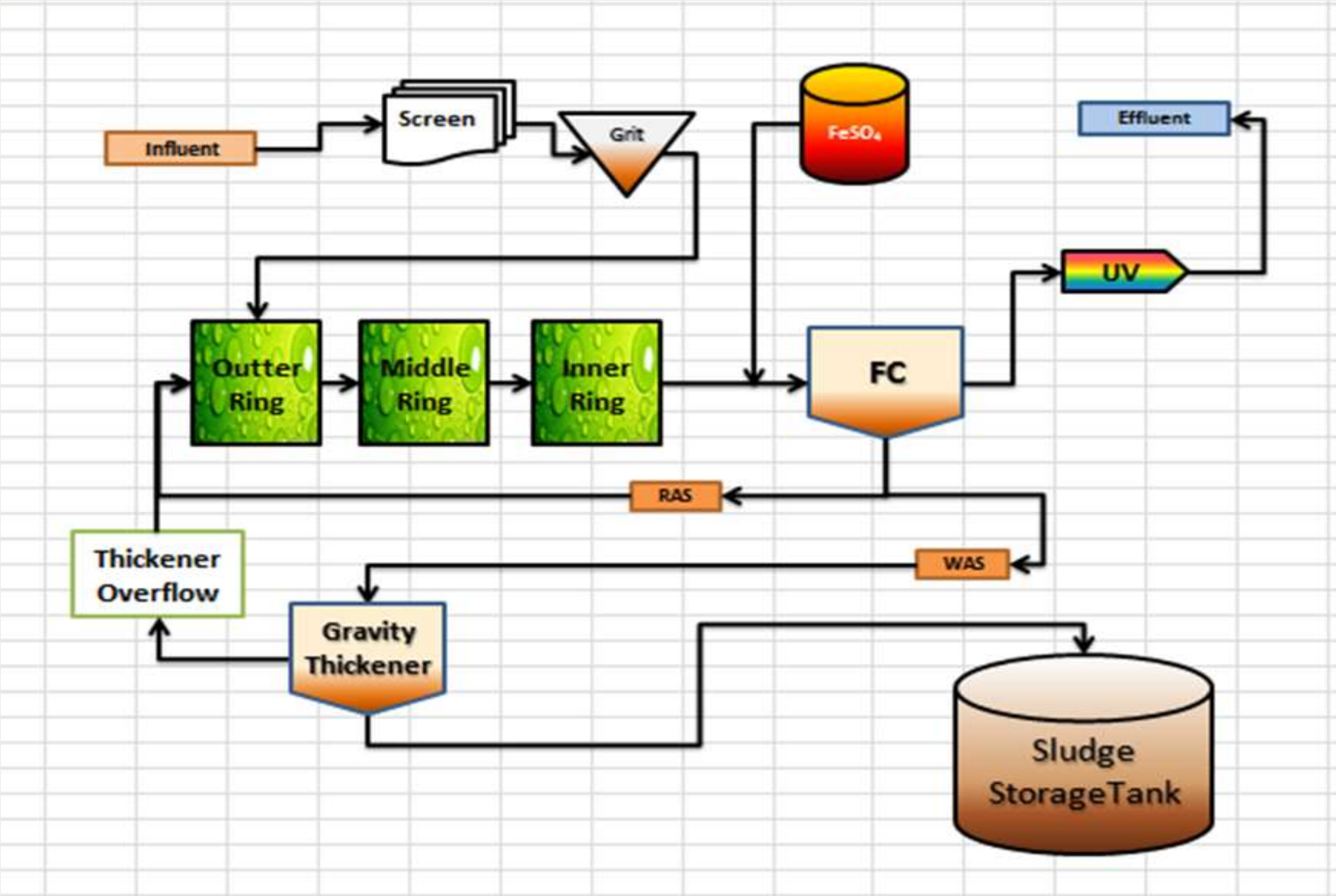
ORP – AN & AB Zone & Delta – Eff TP



Slinger

SLINGER

- Outer ring anaerobic zone and fermentation
- RAS is split between outer & middle rings
  - Promotes growth of Tetrasphaera species, see info later



Slinger WWTP

Monroe

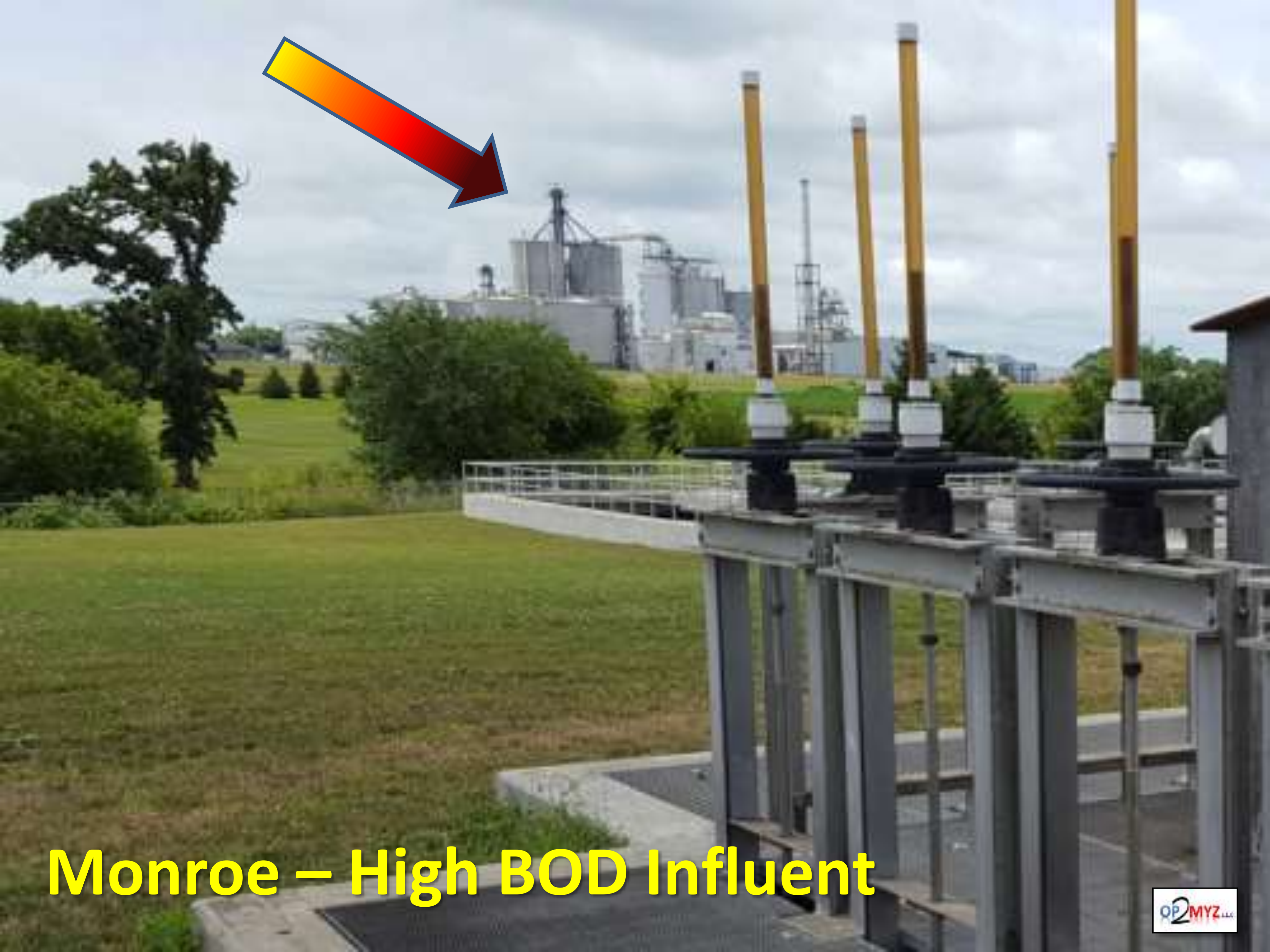
Low ORPs in Anaerobic Zones (-400 to -500 mV at times)

Fermentation in EQ (Also VERY High BOD loading) **drive ORP down**

Sand filters

Eff. TP - 0.1 to 0.15 mg/l levels

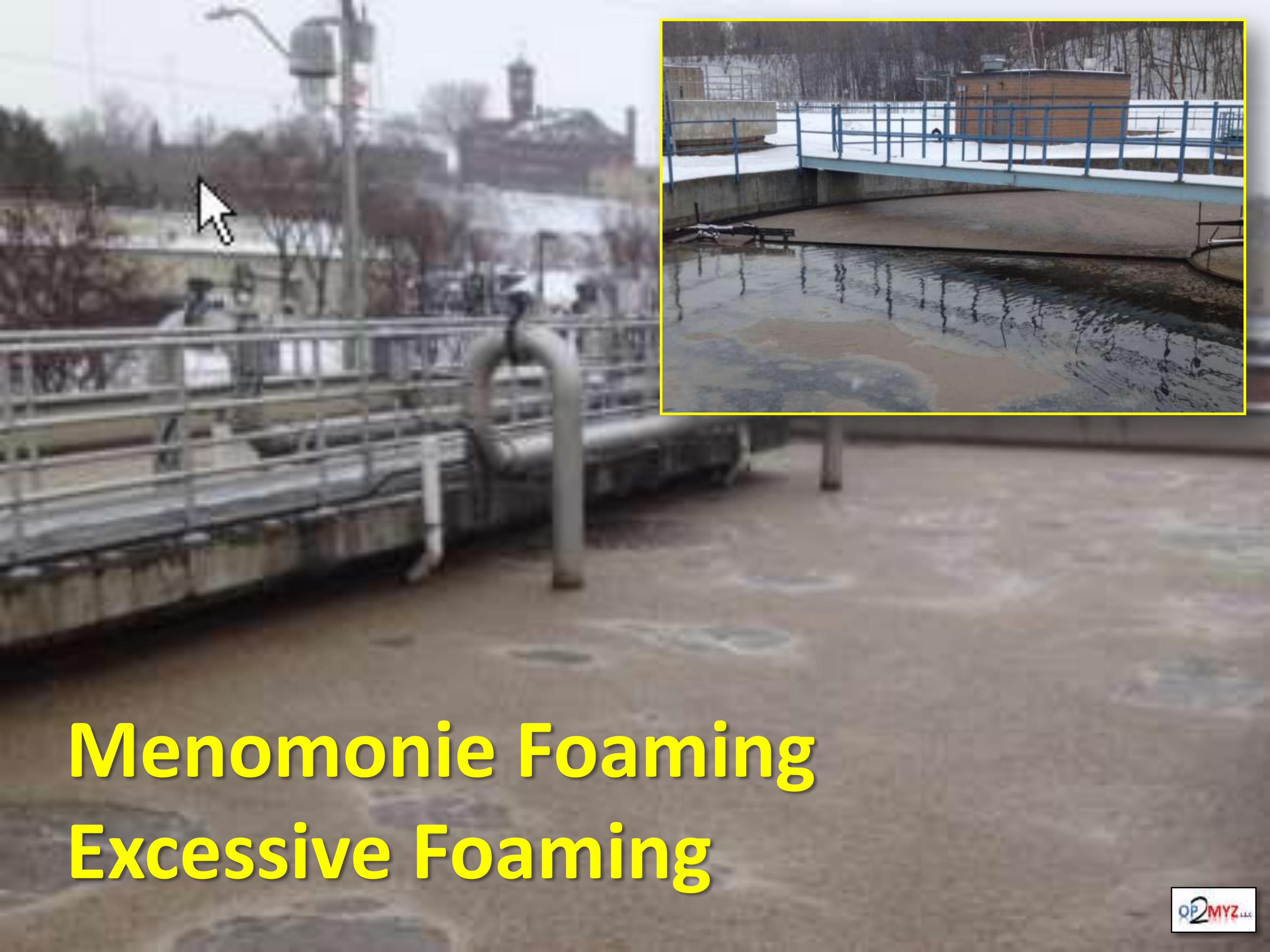

Monroe – EQ Tank


Monroe – High BOD Influent


Monroe

Potential Problems
Potential Fixes

1. Produce more sNRP
   - Compare with Anaerobic Digestion
     - Breakups of floc
     - Produce sNRP (organic P cell matter)
   - **Alum or Iron + filters or INCREASED alkalinity**
2. Excess VFAs – filaments
   - **Reduce SRT of fermentation**
3. GAOs – **low pH INCREASE alkalinity**
4. OPR too low – more likely to have P-release in Final Clarifier – **Increase aeration D.O. setpoint**



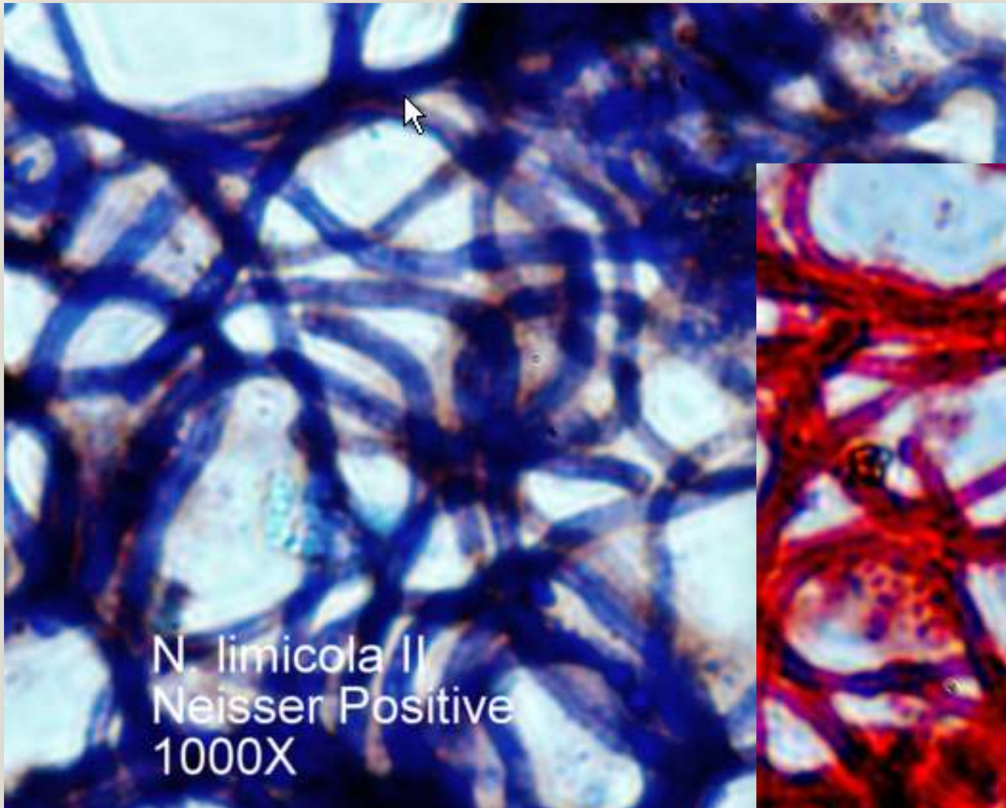
Menomonie Foaming
Excessive Foaming

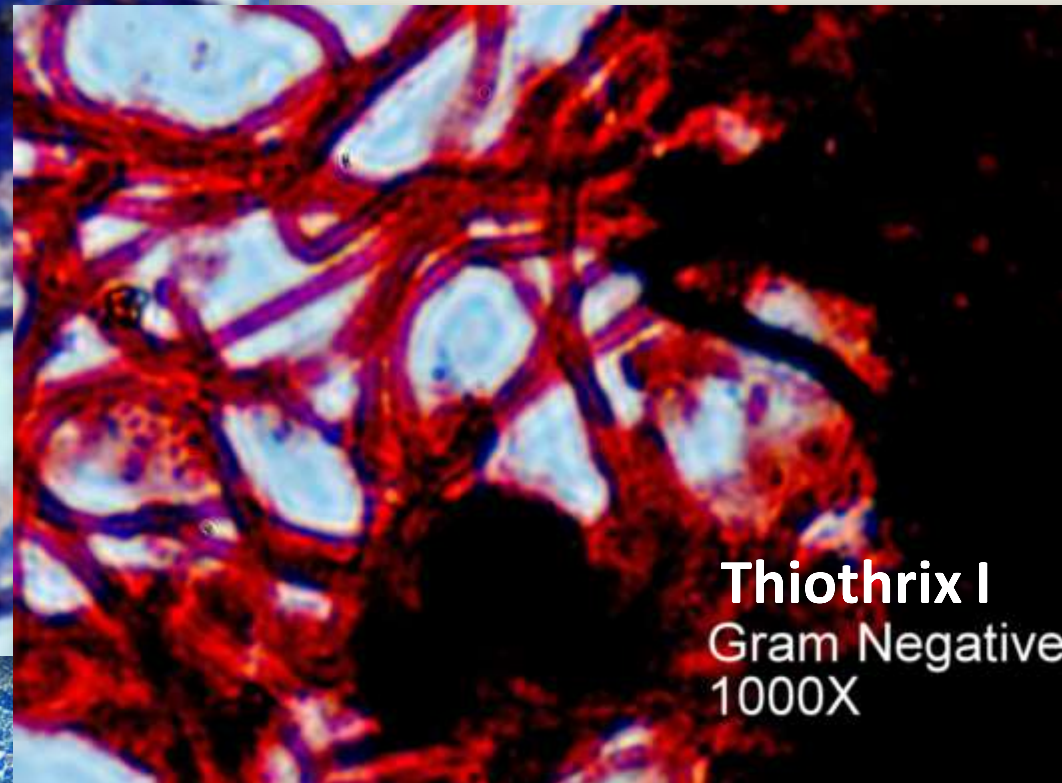
MENOMONIE FOAMING

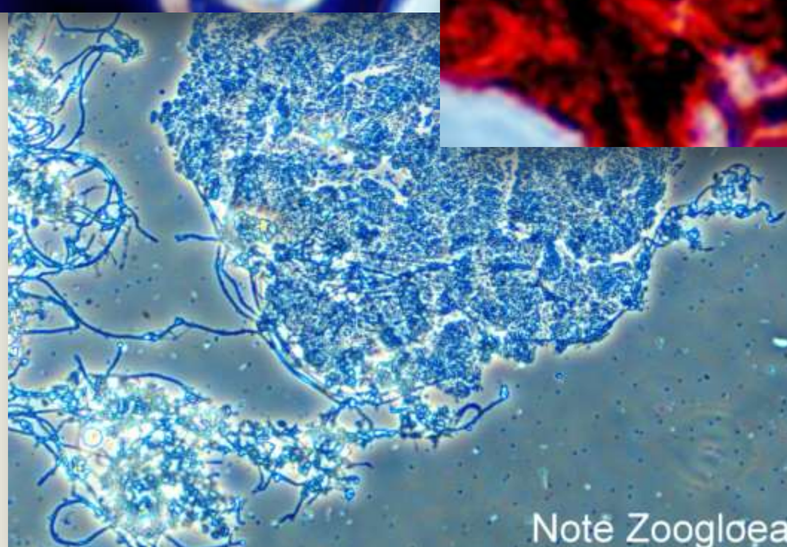
Organisms which grow under HIGH organic acids (acetic, propionic and butyric acids)

- N. limicola II
- Thiothrix I
- Zoogloea

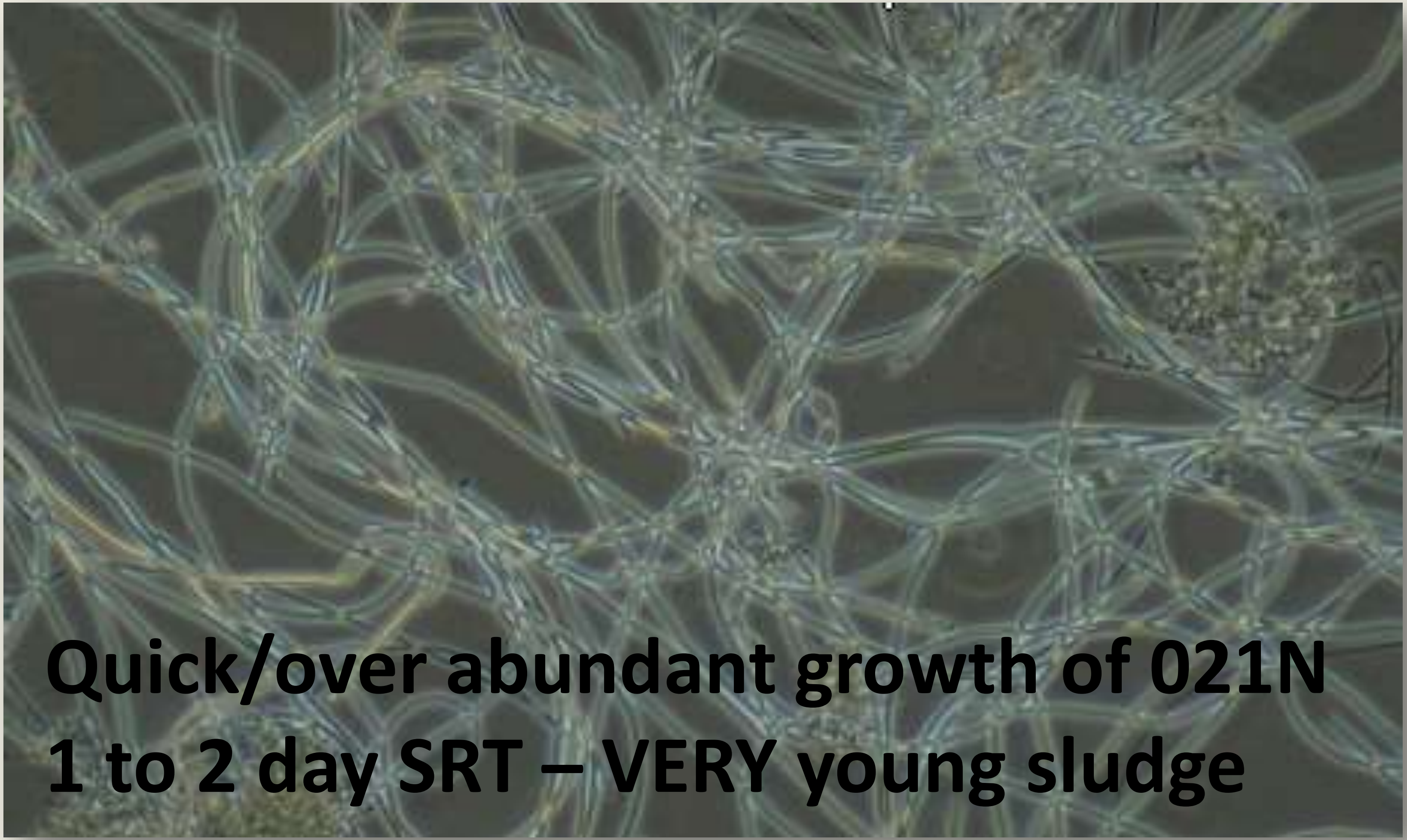
Info/Pics from: Michael Richard Wastewater Microbiology LLC report for Menomonie WWTP


N. limicola II
Neisser Positive
1000X


Thiothrix I
Gram Negative
1000X


Note Zoogloea

Steven Point – OVER DOSE CARBON



Indigo Water Group – Littleton CO
EBPR – pH & GAOs

– Low pH can reduce & even prevent BPR
– Maintain pH in aeration basin >6.9
– Maintain pH in anaerobic zone >5.5
– pH > 7.25 in **anaerobic zone** inhibits GAOS

Aeration Tank/Final Clarifier D.O.

Clarifier P-Release vs. Feed D.O. & Clar. SRT

Technical Article – Phosphorus Management
Knowledge-Based Practices for Achieving
EBPR Reliability by Samuel Jeyanayagam

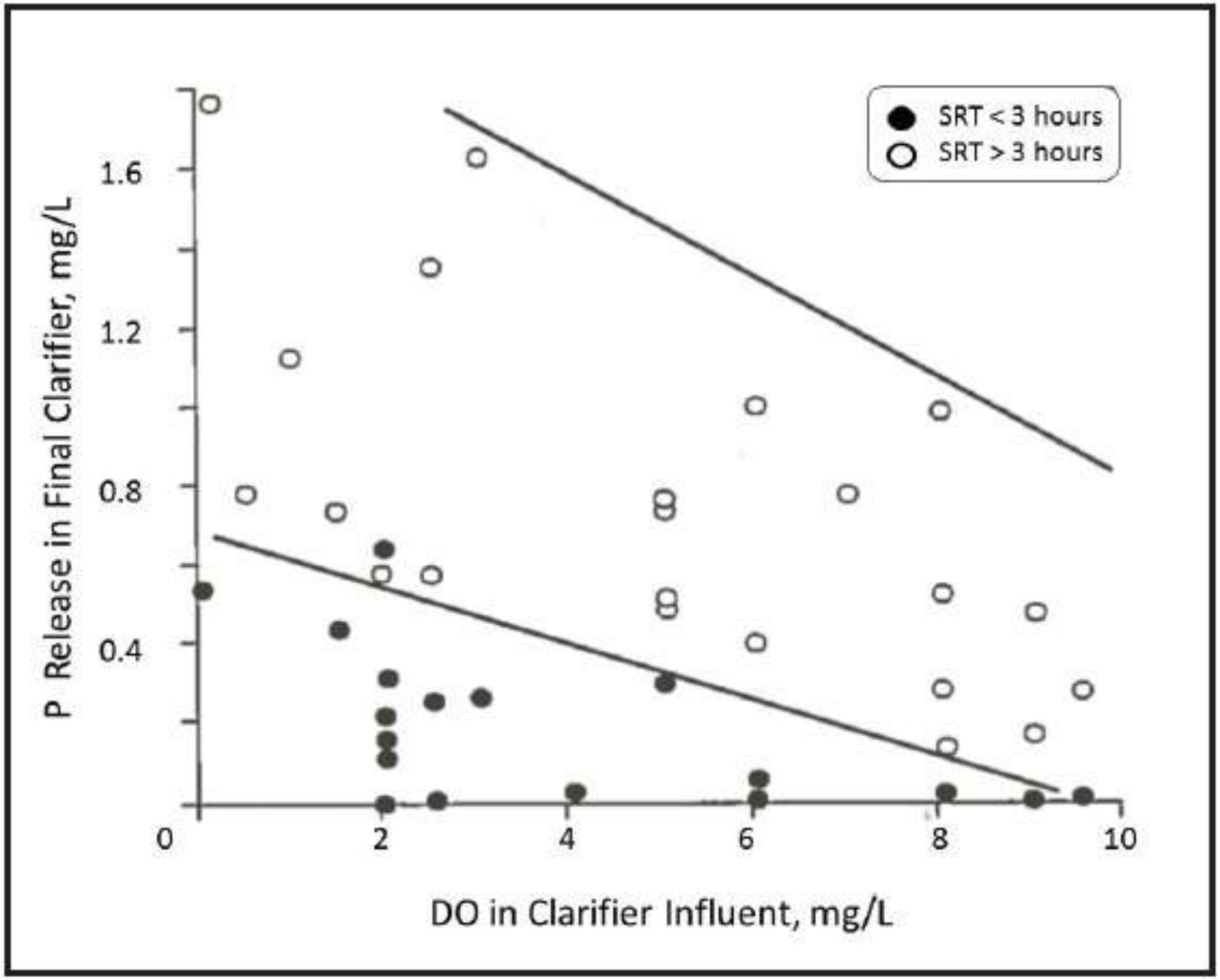


Figure 6: Clarifier P Release as a Function of Feed DO and SRT in the Clarifier


CURRENT
RESEARCH

Rethinking the Mechanisms of Biological Phosphorus Removal

James L. Barnard[1*], Patrick Dunlap[1], Mark Steichen[1]

Nov 2017

ABSTRACT: Enhanced biological phosphorus removal (EBPR) was observed in high-rate, non-nitrifying plants in the United States that were operated in a plug-flow mode. In facilities designed for nitrification and denitrification, a first-stage anaerobic zone, free of nitrate and nitrite was needed to accomplish EBPR, and this is referred to as the Phoredox (a.k.a. the AO and A2O) process. When a biological mechanism responsible for EBPR was proposed, these treatment configurations were accepted as normal practice, but many later observations showed that more reliable phosphorus removal could be achieved with alternative configurations. This paper discusses the development of alternative configurations for EBPR and the likelihood that a host of phosphate accumulating

began (Milbury et al., 1971). Barnard (1974) operated a four-stage anoxic/aerobic/ anoxic/aerobic activated sludge pilot plant shown in Figure 2 for nitrogen removal and observed phosphorus removal from approximately 9 mg/L in the influent to less than 0.2 mg/L as ortho-phosphorus in the effluent. There was a release of phosphorus to more than 30 mg/L in the second anoxic zone and, having noted the release of phosphorus in the other high rate processes, Barnard postulated that when activated sludge passed through anaerobic conditions it would stimulate phosphorus accumulating organisms (PAOs) to release phosphorus and then take up all of the released phosphates and most of the influent feed phosphate during aeration.

Having failed to create similar anaerobic conditions in the

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http://www.ingentaconnect.com/contentone/wef/wer/2017/00000089/00000011/art0001?

Rethinking the Mechanisms of BPR

- Conventional design BPR grow **INEFFICIENT** PAOs. More efficient designs promote growth of numerous types of PAOs – including Tetrasphaera (**TA**)
- **TAs** can
  - Some can Ferment higher carbon forms – produce VFAs for other PAOs
  - Most can denitrify and UPTAKE P in process – **ANOXIC ZONE**

Rethinking the Mechanisms of BPR

- TA is a broad class of bacteria
- Can ferment complex organic molecules
  - Carbohydrates
  - amino acids (including glucose, glutamate, aspartate)
  - Produce stored carbon in the process
  - Req's lower ORP than normal (-300 mV or lower)
- Some TA take up VFA for carbon storage – NOT preferred

Rethinking the Mechanisms of BPR

- **Some TA types MAKE VFA** (and other stuff)
  - Under reduced anaerobic fermentation conditions
  - VFAs are used by other PAOs
- **Creating lower ORP conditions – to grow TA**
  - Remember Laws of ORP
  - Don't over mix
  - Limit primary influent (storm flows/etc.) into anaerobic zones - decreases HRT
  - Less RAS to Anaerobic zone more to Anoxic zone
  - Keep anaerobic SRT high – ON/OFF mixer cycling assists with this

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DNAmyWastewater™ (Microbe Detectives™)

Canonical Name (Previous Name)	Fermented.Overflow. [redacted] (% of Total Bacteria)	Mixed.Liquor.[redacted](% of Total Bacteria)
Fermenters		
Actinobacteria	8.51%	1.88%
Firmicutes	27.78%	6.56%
Propionivibrio	0.03%	0.58%
Tetrasphaera	0.00%	0.31%
Propionicimonas	0.00%	0.00%
Streptococcus	1.50%	0.22%
Lactococcus	0.07%	0.13%
Phosphorus		
Defluviicoccus (GAO)	0.00%	0.00%
Dechloromonas	0.00%	0.00%
Accumulibacter - PAO	0.00%	0.00%
PAO related p__Proteobacteria;c__Betaproteobacteria;o__Rhodocyclales;f__Rhodocyclaceae	0.11%	5.91%
Tetrasphaera	0.00%	0.31%

TA In both Fermenter/Phosphorus categories

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Thank You
Any Discussion, Comments or Questions

- Op2Myz, LLC
- Providing a "bridge" between WWTP operators in understanding, troubleshooting and optimizing their biological phosphorus & nitrogen removal systems.