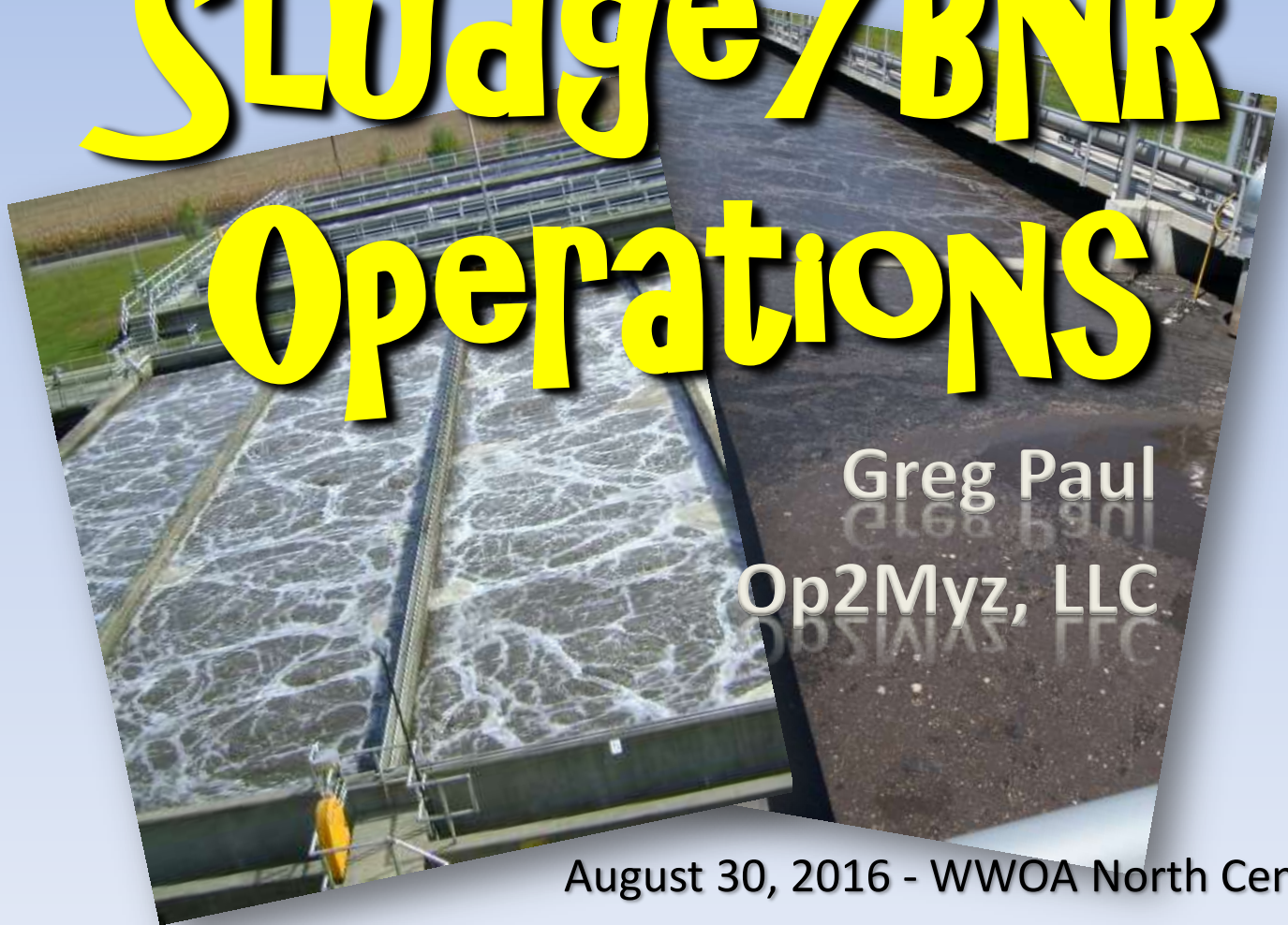
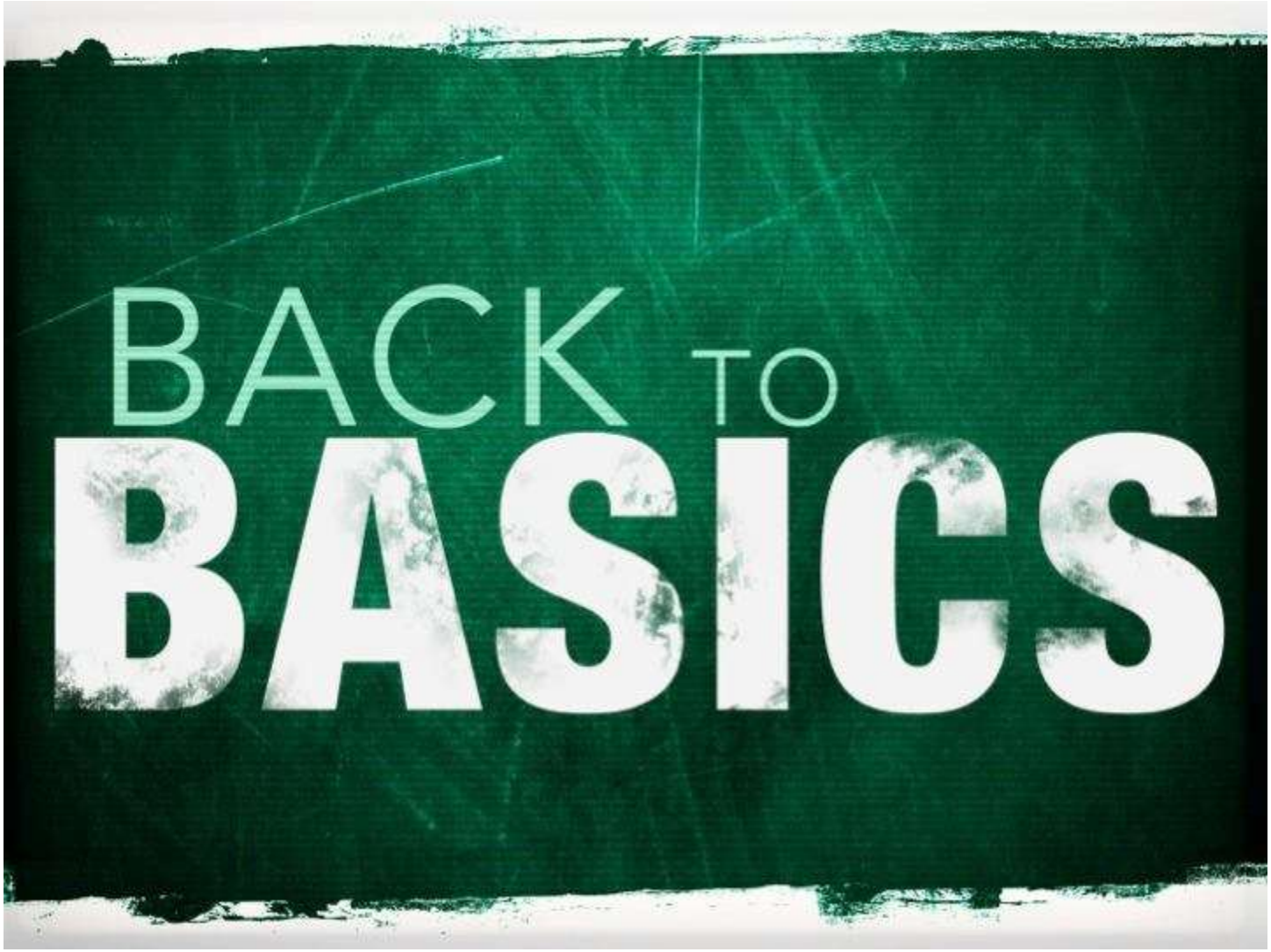
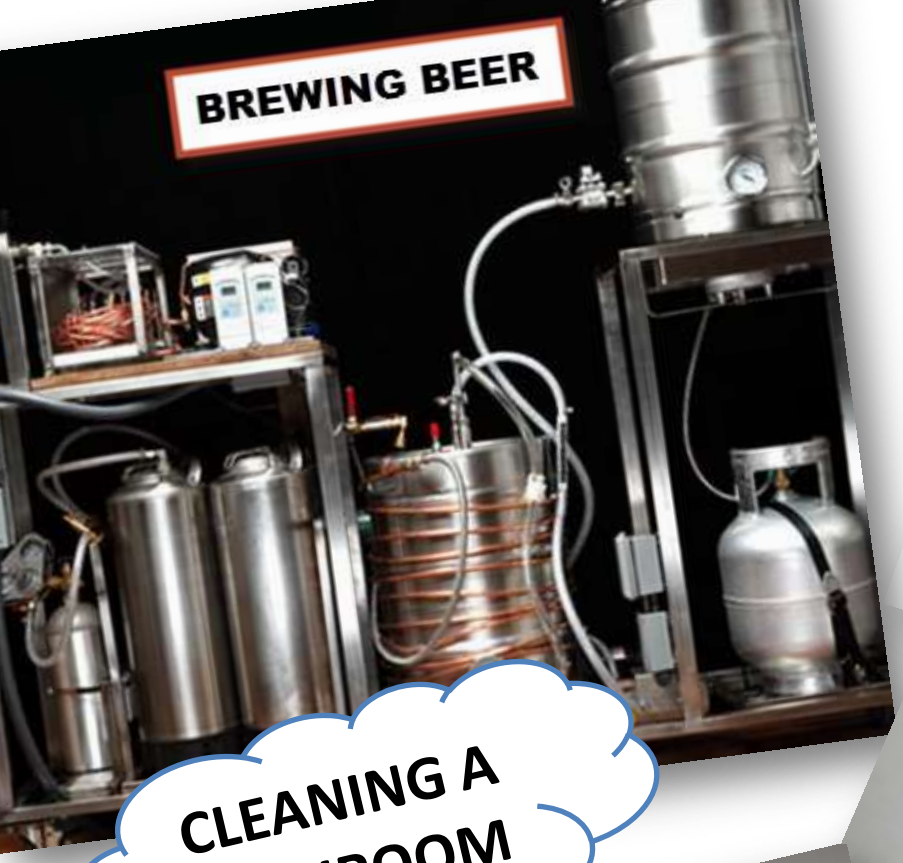
Activated Sludge/BNR Operations

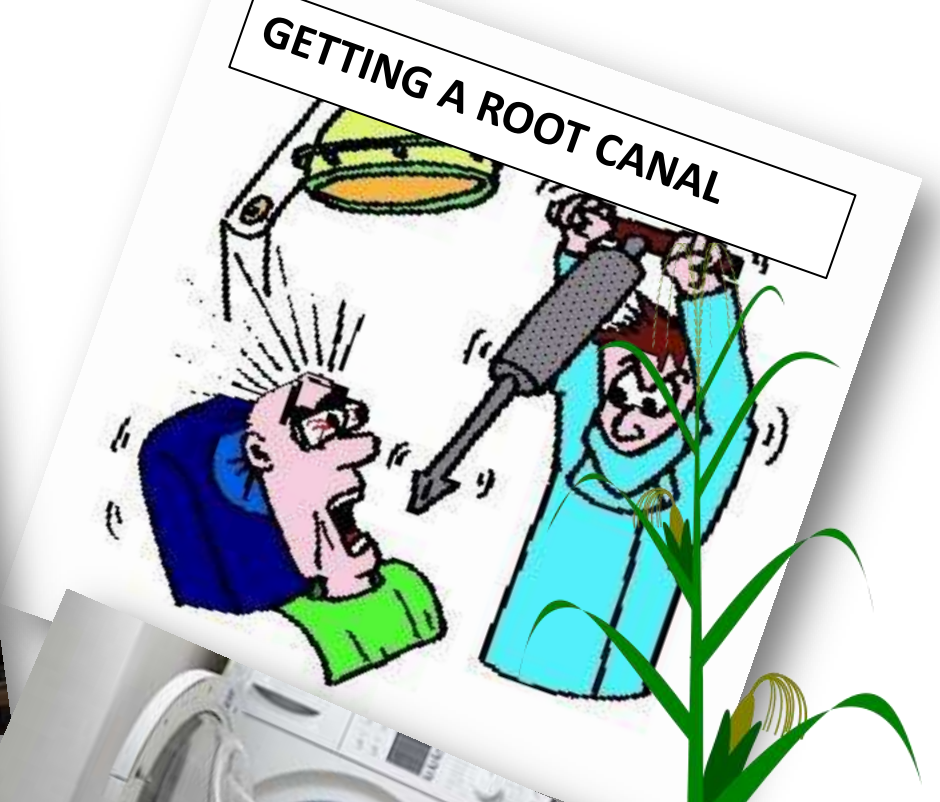


Greg Paul
Op2Myz, LLC

August 30, 2016 - WWOA North Central Meeting


BACK TO
BASICS





CLEANING A BATHROOM

GROWING CORN

WHAT DO THESE ALL HAVE IN COMMON


BREWING BEER
GETTING A ROOT CANAL
WWTP
CLEANING A BATHROOM
GROWING CORN
DOING LAUNDRY
WHAT DO THESE ALL HAVE IN COMMON

They all involve manipulation of environments to grow specific microbiological organisms or to just minimize/control specific organisms from growing.

We Are Bug Farmers

- Engineers provide biological environments designed to grow specific bugs
- Operators use all their available tools and ingenuity to grow the bugs whom produce the best quality products – clean water and a useful fertilizer

Ok, with an
Activated Sludge system
What do I Key IN on For
Growing the Right Bugs?

How do I Control an
Activated Sludge System?

Activated Sludge: Goals and Bug Selection

- The treatment goals - Reduce BOD (dissolved sugars), TSS, fecal coliform and maybe some ammonia
- System/Operation selects for heterotrophic and autotrophic bugs –
- In most cases these Bugs require AEROBIC environments to do their work

Key Controls for Activated Sludge

- So then its all about provide the right amount of oxygen, sludge and appropriate RAS rate to achieve treatment
- Activated Sludge – mostly AEROBIC BUGS
  - Continuous aeration/settling/waste/RAS
  - D.O./SRT - MLSS/RAS – Blanket/Microscope

WASTING – TOO many & TOO few BUGS !!!

If There Is Talk of
Re-configuring to BPR or BNR
OR
It Has Already Been
Re-configured
.....

Now What Bugs Do I Grow?!?!

BPR/BNR Systems
Goals and Bug Selection

- Goals are all the same as Activated Sludge system **plus……**
  - Reduce BOD (dissolved sugars), TSS, fecal coliform
  - Plus biological **phosphorus** removal(BPR)
  - Or for BNR - biological **phosphorus** and **nitrogen** removal

BPR/BNR Systems
Goals and Bug Selection

Bug Selection

- In these systems/operations you also **select** for heterotrophic and autotrophic bugs with an additional twist
- **Select** for facultative heterotrophic bugs vs. aerobic heterotrophic bugs
- Now these Bugs require ANAEROBIC and AEROBIC environment to do their work
- In the case of BNR they will also need an ANOXIC environment

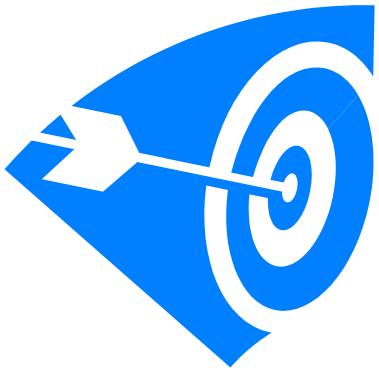
Key Controls for BPR/BNR Systems

- Now its all about providing the right amount of oxygen **(varied amounts of oxygen in varies locations), the right Food in the right place,** sludge and appropriate RAS rate to achieve treatment
  - Cycling air ON/OFF (AN/AB)
  - Proper BOD:TP into AN Zone
  - ORP/Aeration D.O./SRT/RAS/Final Clarifier D.O./ Blanket Control/Microscope
  - Controlling nutrient rich recycle side stream

Simplistic Summation

Meet BOD Demand and Keep "P" Tied Up

Bringing it All Together
BOD Demand vs. Total Available BOD



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

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

Define Total BOD Demand

The sum of all BOD necessary to satisfy the follow;

- Biological Phosphorus Removal **(BOD:TP)**
  - Approx. 20 lbs. BOD Required/lb. of P removed
- NO_3-N removed in anaerobic and/or anoxic zone **(BOD: NO_3-N…or BOD:N)**
  - Approx. 4 lbs. BOD required/lb. of NO_3-N removed
- BOD necessary to deplete excess O_2 coming in AN zone **(BOD: O_2….or BOD:O)**
  - Approx. 1.7 lbs. BOD required/lb. of O_2 removed

Cycling air ON/OFF (AN/AB)

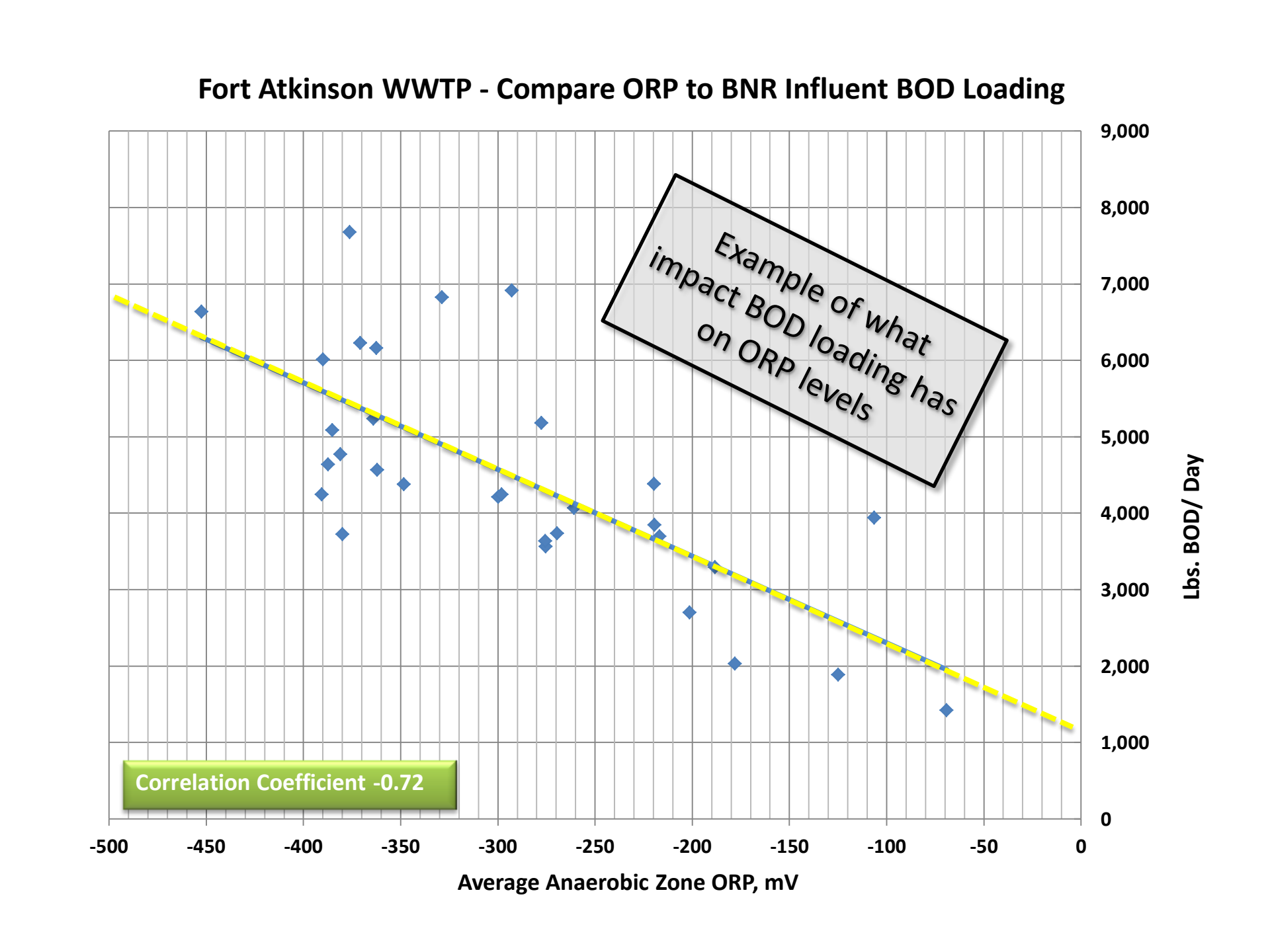
- Anaerobic (An) Zone – truly anaerobic
- Aerobic (AB) Zone – Levels vary based on type of system
- AN Zone – Truly Anaerobic
  - How do know if you're AN zone it truly anaerobic – ORP less than -150 mV
  - Online ORP meter is the best way to optimize and understand the hourly impacts of Total BOD demand

ORP - VERY IMPORTANT when operating BPR/BNR

- It roughly tells you whether you have enough food to cover all of the energy demands of the bugs,
  - In the cases of achieving very lower eff. soluble Reactive Phosphorus (sRP) levels the conditions in AN zone are right to produce more VFAs to complete the bug's demand
- **High ORP** - Bugs don't have enough food (VFA) to meet all the demands put on the bugs in order to do their job of P & N removal
- **Low ORP** - There is a good chance the bugs demand for food is met or close to being met

Figuring Out Why AN Zone Has a **High ORP**

- ORP in AN zone will tell you if….
  - BOD:TP is high or low
  - NO_3-N are high or low
  - O_2 is high or low
  - When any of these or multiples of these are having a negative affect the AN zone


Fort Atkinson WWTP - Compare ORP to BNR Influent BOD Loading
Example of what impact BOD loading has on ORP levels
Correlation Coefficient -0.72
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Lbs. BOD/ Day
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
Average Anaerobic Zone ORP, mV

Figuring Out Why AN Zone Has a High ORP

- When you don't know if poor BOD:TP, high NO_3-N or high O_2 are having the negative effect then….
  - Investigate to find out – Check RAS & Inf. O_2, Test side streams for P & N and Eff. NO_3-N (Approx. same as RAS) **these last 2 usually have biggest negative impact on BOD:TP (ORP)**
  - Or adjust AN zone operation to overcome negative impact
    - ORP will keep you abreast of your progress or lack of progress
  - Or do a combination - find out issue & address it if possible PLUS adjust AN zone operations

Thoughts on Tracking Testing BPR/BNR

- Data - More is good for data (to a point) – for a better understand your system
- You could test
  - BNR Influent - VFAs, sBOD, sCOD, TP, sRP
  - Effluent – sRP, TP, sTP
  - All AN zones – ORP, sRP, NO_3-N
  - All AB zones – sRP, NO_3-N, NH_3-N
  - All side streams - sRP, NO_3-N, NH_3-N
- **Minimalist Approach** – you need to know what is most important
- The MAIN question you need to answer is "There is enough food for the bugs (BOD or VFA) to drive the bio-P reaction"? If there isn't enough food the reaction wouldn't happen.
- How do you economically answer that question - ORP

ORP - VERY IMPORTANT when operating BPR/BNR

- **High ORP** - bugs don't have enough food (VFA) to meet all the demands put on the bugs in order to do their job of P, N & O_2 removal
- **Low ORP** - There is a good chance the bugs demand for food is met or close to being met

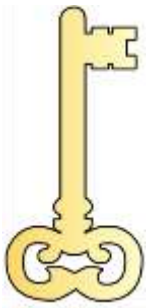
A Look at Other BPR/BNR Controls

- **Aeration Tank D.O.** – 2.0 to 5.0 ppm in first AB zone, 1.0 to 2.0 ppm in the rest
- **SRT** – generally maintain enough SRT/MLSS to just achieve nitrification – eff. NH_3-N just above detection.
- **RAS** rate fast enough so ORP in sludge blanket does get too low (P release) but not too fast so you decrease AN zone HRT
- **Maintain D.O. in final clarifier** or 1.0 to 1.5 ppm to prevent P release. Control by…
  - AB zone D.O.
  - RAS rate & SRT/MLSS levels

IMPORTANT - Controlling nutrient rich recycle side streams

- Scheduling dewatering/thickening operation
- Minimize nutrient concentrations in recycle
  - Aerobic digester –
    - Operation and/or chemical
  - Anaerobic
    - Chemical
    - Struvite
      - How do economically handle struvite
- EQ tanks or system

Dealing With Side Streams



BOD:TP
BOD:N
BOD:O

WWTPs Commonly Start Here

Much bigger than Available

Total BOD Demand, lbs./hr.
This is total lbs. BOD to satisfy P & N removal requirements

VS.

Much smaller than Required

Total Available BOD, lbs./hr.
This is total lbs. BOD available in the influent to system plus any supplemental BOD provided

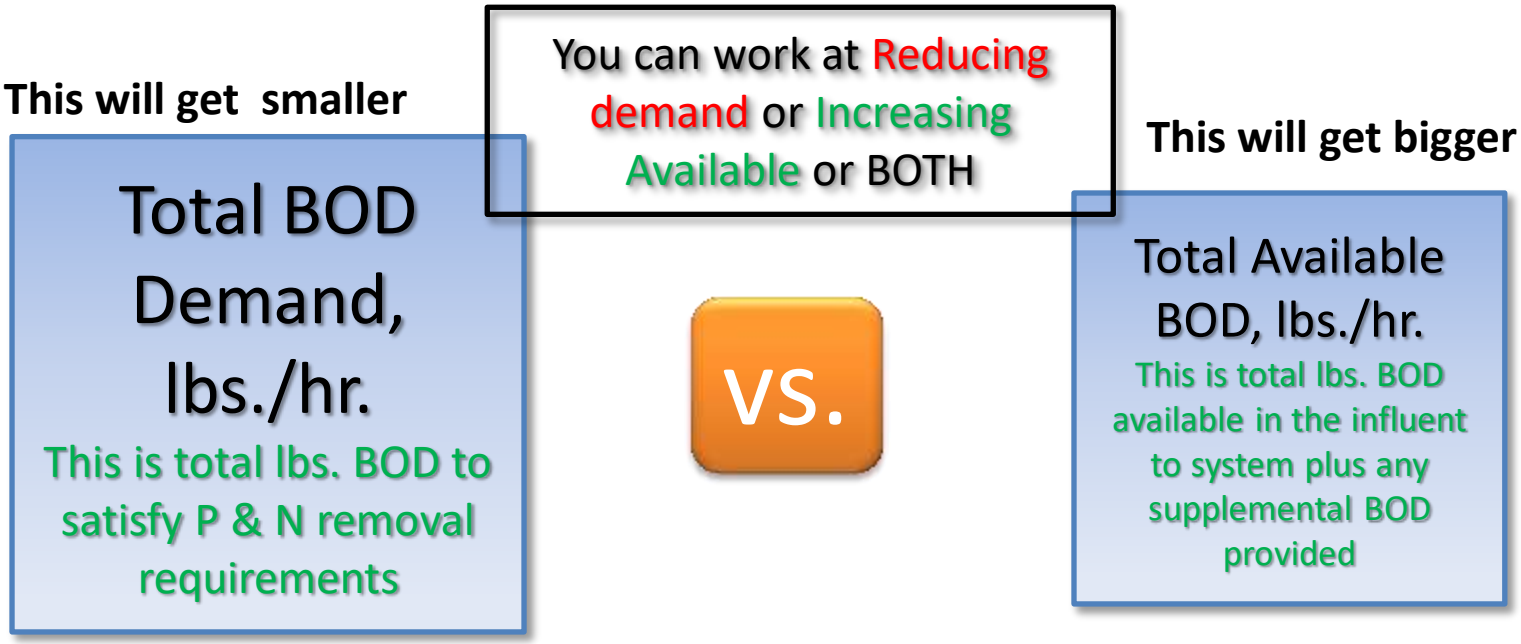
BOD demand, #/hr. high because;

1. Digester operations produced more P & N
2. Decanting & centrifuging operation were concentrated into short periods of time creating VERY HIGH P & N loads
3. NO_3-N in RAS

Available BOD, minimal;

1. Only source of BOD the influent wastewater

Discuss Possible Improvements



BOD:TP ⇩

BOD demand, #/hr. reduced because;

1. Digester operations is producing less P & N
2. Decanting & centrifuging operation more equalized - spread out over longer periods reducing the hourly BOD demand creating less hourly demand P & N
3. Add ferric to side streams to reduce P demand

BOD:TP ⇧

Available BOD increased;

1. Providing two sources of BOD (VFAs) the influent wastewater and inline fermentation

What more can be done?

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

BOD:TP ⇩

BOD demand, #/hr. How do we decrease this more?

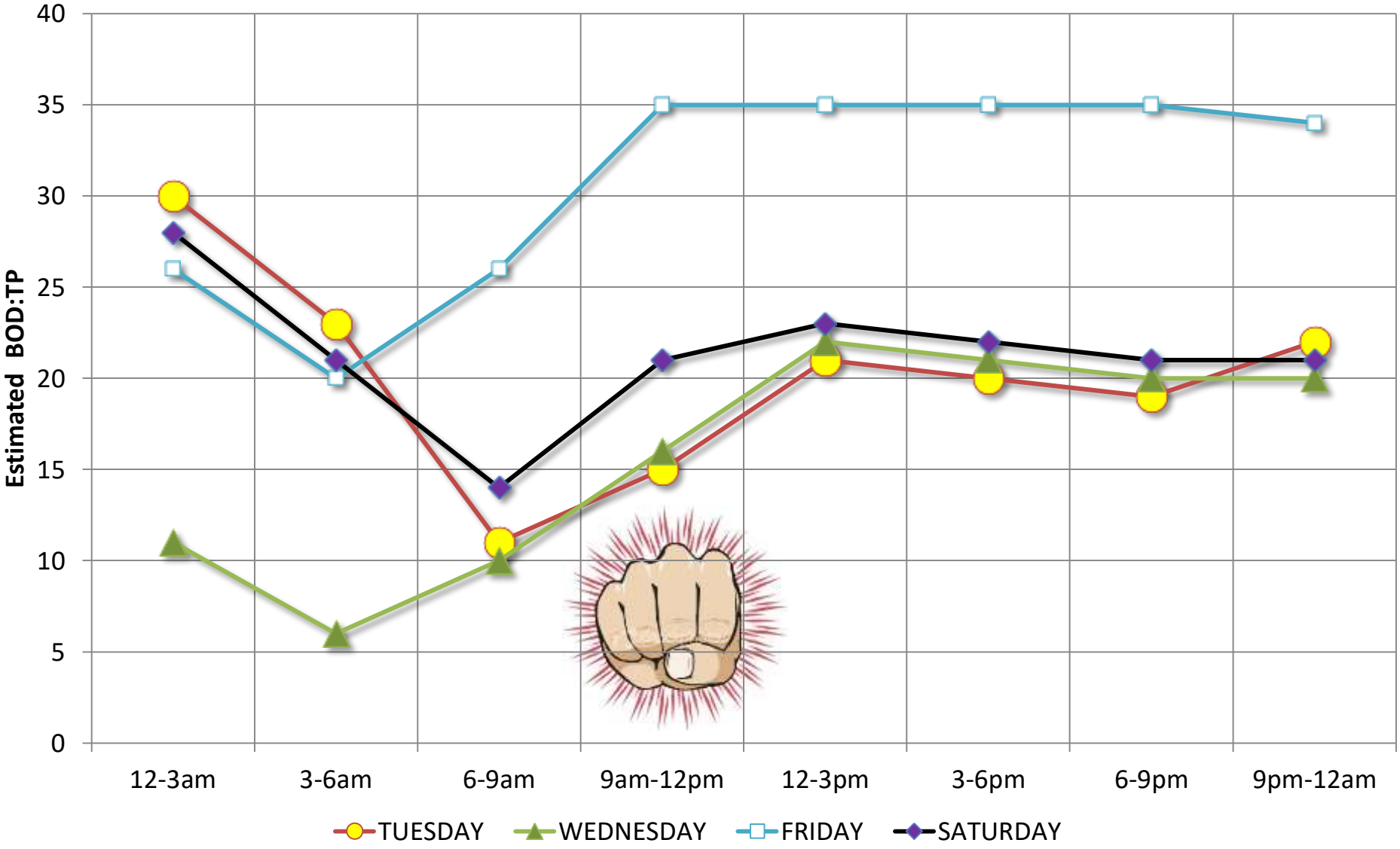
1. Improve digester operations more
2. Improve scheduling/operational practices for decanting & centrifuging operation spreading out the discharges over longer periods

BOD:TP ⇧

Available BOD, #/hr. How do we increased this more?

Better fermentation and/or supplemental feed (QLF)

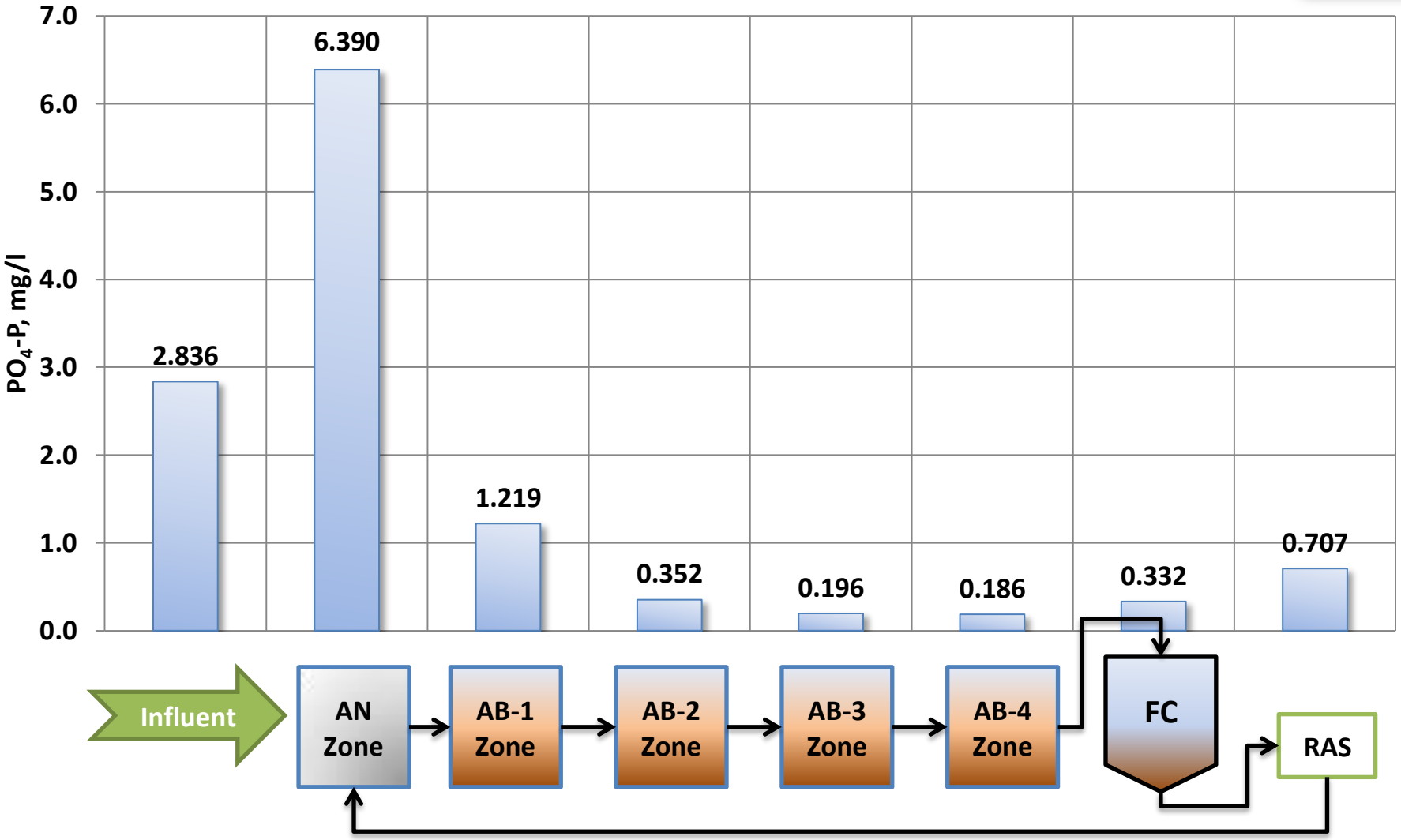
Example of Impact on Inf. BPR
BOD:TP Ratio from Side Stream P & N



Chemical P Removal vs. BPR

- Chemical is very straight forward, need to get rid of more P turn the chemical feed up
  - Watch as the P comes out of the effluent and fills up your sludge storage
- BPR requires more operator attention and additional level of understanding of the **bUgS** you're growing but…there's a pay off
  - You produce less sludge – reduce chem$ and land application$
- **NOTE - BPR/BNR still needs some chemical treatment for side stream control, struvite and backup eff. polishing**

P-Profiles to Help Understand System
Medford WWTP - PO_4-P Profile, mg/l



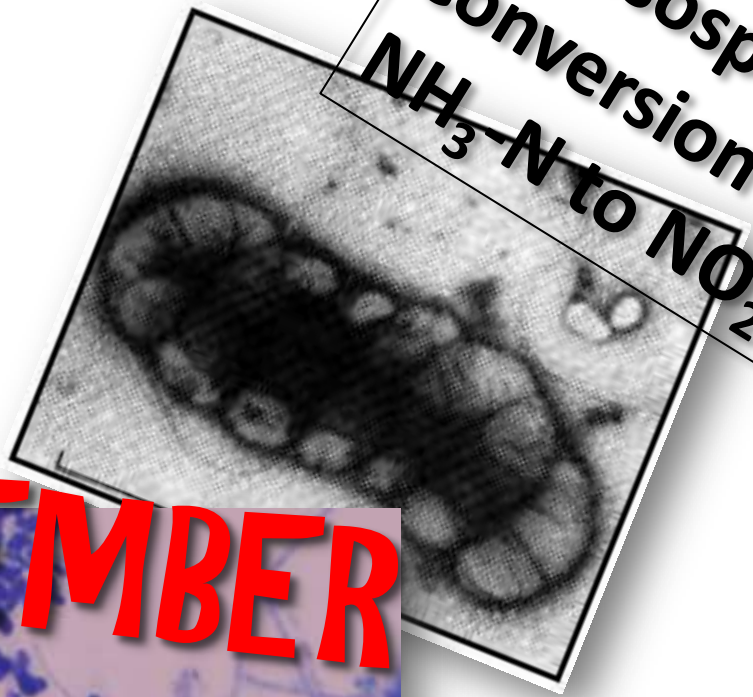
What about Online Analyzers/Probes/Automation

- Online P-analyzer
  - Extremely helpful for ID operational/loading issues
- Online OPR – good understanding of Total BOD demand
- Online TSS analyzer –
  - with PLC or Purchased unit –
  - calculate SRT
  - Keeps SRT very steady
- Personal experience with analyzer/automation at La Crosse – Other operators too
- **Maintenance required – otherwise don't buy it!!**
  - **Figure maintenance cost when figuring cost unit!**

The Four (4) most important things in BPR/BNR

- Control of side stream nutrients
- Having a truly anaerobic zone
- Having enough D.O. to uptake the P released in AN zone
- AB zone uptakes P, and **keeps it within the cell until it gets to the AN zone or is wasted out.**

Nitrosospira
Conversion
NH_3-N to NO_2-N



REMEMBER
We Are Bug Farmers

Phosphate Accumulating Organism - PAOs

Greg Paul
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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.