Bio-P Operational Changes and Impacts

CSWEA Phosphorus/Nutrients Operations Seminar
Nov 14th 2019

Op2Myz, LLC – Greg Paul
UP FRONT
This info/Discussion is from simple observation and study at Numerous WWTP...
It is on going
Thanks to Those Who Have Shared

- Antioch
- Lindenhurst
- Medford
- Eleva-Strum
- Slinger
- LaCrosse
- Lake County, IL
- Many others
Grandpa, are you going to be the Oldest Person There?
WANT TO GO DEEPER

• Essentials →
• Floc – FLOCOLOGY (study of floc)
  – Young/Old
    – Big/Small
    – Positive/Negative
    – Slime Layer
    – pH/Alkalinity
• Floc’s Impact on EBPR Removal Efficiency
  – Fermentation
  – Uptake
  – TSS capture
### Activated Sludge Log

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<tr>
<th>Time of Day</th>
<th>Int</th>
<th>Pump On/Off</th>
<th>Pump Speed, Hz</th>
<th>Weekday Min/cycl</th>
<th>Week End Min/cycl</th>
<th># of Cyc per day</th>
<th>Scum on Anaerobic Zones</th>
<th>Foam on Aerated Zones</th>
<th>Scum on Final Clarifier Surface</th>
<th>Scum in Final Clarifier Centers</th>
<th>Which is Final Off</th>
<th>Eff/HR Avg</th>
<th>SRT</th>
<th>Try</th>
<th>Did it Work?</th>
<th>Comment</th>
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<tbody>
<tr>
<td>1/16/00</td>
<td>5:00 PM</td>
<td>GJP</td>
<td>on</td>
<td>45</td>
<td>15</td>
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<td>30</td>
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<td>6</td>
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<td>2/23/06</td>
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<td>GJP</td>
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<td>45</td>
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<td>35</td>
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<td>Calculating wasting settings</td>
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### Foam/Scum Key

- **Qty.** 0-None, 1-Small Amount, 2-Approx. Half, 3-Covered
- **Color.** W-White, T-Tan, B-Brown, D-Dark Brown, G-Gray, BK-Black

**Video/Pics/Files**
- 080507-Aeration-Foam-Scale.pdf
- 080428-Aeration-Scum-Scale.pdf
- 060311-Calculating-Wasting-Rates-Settings.xls
- 060311-Operational-Changes.doc

### Graphs

- **MLSS & Clarifier Blanket, ft.**
  - 21 per. Mov. Avg. (MLSS, mg/l)
  - 21 per. Mov. Avg. (Heavy Sludge Depth, ft.)

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**Recordkeeping/Trends/Investigate**

What, Why, When, Where and How

November 14, 2019
........FLOCOLOGY........
O₂ Just Right

TOO MUCH O₂

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Young Sludges

Not Enough O₂
ORP Just Right

ORP too Low

ORP Too High

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www.sustainopedia.com/activated-sludge-troubleshooting-through-microscopic-evaluation/

web.deu.edu.tr
We Live in a

CHARGED WORLD

Positive/Negative
VERY SIMPLY- It is a measurement of an positive/negative electrons in a liquid

Industrial Strength Zapping!!!
Oxidation-Reduction Potential
Info from WEF MOP 37

- Oxidation-Reduction Potential is a measurement of the ABILITY of a solution to accept or donate ELECTRONS.

  + Positive ORP ability to ACCEPT electrons (oxidative environment - oxygen)

  - Negative ORP ability to DONATE electrons (reductive environment - no oxygen)
From http://www.rhtubs.com/ORP.htm

From Robert's Hot Tubs!!!

- ORP Meter is **REALLY** just a millivolt meter, measuring the voltage across two electrodes

“Oxidation-Reduction” is used with a hyphen because the two chemical reactions are really "joined at the hip" - **one cannot occur without the other also occurring**
Electrically Charged Microbes

- Bacterial cell walls are negatively charged
- Charges change based on environment
SLIME LAYER
Slime Layers on Microbes

- **LPS** (Lipopolysaccharide) is a major component of the outer membrane of Gram-negative bacteria, contributing greatly to the structural integrity of the bacteria, and protecting the membrane from certain kinds of chemical attack. Endotoxins.

- **EPS** (Exopolysaccharides or Extracellular polymeric substances) are compounds secreted by microorganisms into their environment.
Why slime layer?

• Slime layer is contains glyco protein\(^{(1)}\) molecules are loosely associated with the cell wall.

• Protection - Bacteria covered with this slime are protected from dehydration and loss of nutrients.

\(^{(1)}\) Contains Nitrogen
How Does EPS Glue Floc Together?

• EPS helps glue floc together physicochemically
  – It glues particles-microbes together by ELECTROSTATIC INTERACTIONS
    • Between the multivalent cations (Ca²⁺, Mg²⁺) and negatively charged EPS
    • Also by hydrophobic interactions

From - Fatty Acids of Lipid Fractions in Extracellular Polymeric Substances of Activated Sludge Flocs
By - Arnaud Conrada, Merja Kontro (Suutari)b,c, Minna M. Keinänenb, Aurore Cadoreta, Pierre Faured, Laurence Mansuy-Huauld, and Jean-Claude Blocka,*
What causes LPS in WWTP?

**Nutrient deficiency and/or toxicity**

BOD:N:P – 100:5:1

*Looking at our digestive track what causes nutrient deficiency?*

**High carbon diets** – 200:5:1

Why is LPS a problem in human biology?

Causes inflammation in any place within the body
LPS in Activated Sludge

(WWTP BIG Gut)

Normal Conditions

“P” Deficient

“P” & “N” Deficient
LPS normal part of cell wall – EPS is produced by LPS

From - Structural Studies of Some Bacterial Lipopolysaccharides and Extracellular Polysaccharides using NMR Spectroscopy and Mass Spectrometry - Semiha Dag
From - Understanding the role of extracellular polymeric substances in an enhanced biological phosphorus removal granular sludge system

Abstract

The role of extracellular polymeric substances (EPS) in the enhanced biological phosphorus removal (EBPR) process was investigated in a P-accumulating granular sludge system by analyzing the distribution and transfer of P, K⁺, Mg²⁺ and Ca²⁺ in the sludge phase, EPS, and the bulk liquid. In the sludge phase, about 30% P, 44.7% K⁺, 27.7% Mg²⁺, 28% Ca²⁺ accumulated in the EPS at the end of aeration. The rate of P, K⁺, Mg²⁺ and Ca²⁺ released from the EPS matrix into the bulk liquid in the anaerobic phase was faster than the rate they were adsorbed from the bulk liquid into the EPS in the aerobic phase. P, K⁺, Mg²⁺ and Ca²⁺ were retained in EPS before transferring into the phosphorus accumulating organisms (PAOs). These results suggest that EPS play a critical role in facilitating the accumulation and transfer of P, K⁺, Ca²⁺ and Mg²⁺ between PAO cells and bulk liquid.

NOTE - P, K, Mg and Ca retained in EPS before transferring into PAOs
EBPR process is known to mainly rely on the ability of phosphorus-accumulating organisms to take up, transform and store excess amount of phosphorus (P) inside the cells. However, recent studies have revealed considerable accumulation of P also in the extracellular polymeric substances (EPS) of sludge, implying a non-negligible role of EPS in P removal by EBPR sludge.

If Ca or Mg is added to increase alkalinity does it also get stuck in EPS and combines with sRP or sNRP ??
US & BIO - SLIME LAYERS

• Plaque
  – Slime Layer in the Mouth
  – Created by *Streptococcus muta*
  – This traps Other microbes too
  – Accumulation on tooth enamel
  – Can be 100’s cells thick
  – Causes Cavities

• Tartar
  – Plaque build-up mineralized

• Nose/mouth/digestive system →
pH - ALKALINITY
pH/Alkalinity

- **GAO** predominance impacted by pH
- pH impacted by alkalinity
- **Alkalinity impacted by**
  - Influent levels – *drink water alkalinity*
  - Levels of *nitrification/denitrification*
- **Alkalinity impacts P removal as well by;**
  - Improved **BIOLOGY** with better pH
  - Slight **chemical** removal impact
  - **Coagulant** impact with colloidal solids (possible sNRP removal)
GAO – pH/Temp/Acetate-Propionate

Figure 7: Population Distribution of PAOs and GAOs (Vazquez et al., 2009)

From - Sam Jeyanayagam Article

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Floc’s Impact on EBPR Removal Efficiency
FERMENTATION
Floc’s Impact on EBPR Removal Efficiency - FERMENTATION

• Minimum ORP in -150 mV – for regular PAOs growth
  – Less than -150 mV better
  – Around -250 an below possible growth of *Tetrasphaera* (high bred PAOs)

• **Theory** – the lower you go the more you hydrolyze your floc
  – Hydrolyzed floc → break into fines (negatively charged)
  – Floc needs more repair
  – If no repair effluent TSS has more fines
    • Colloidal solids – sNRP ???

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...... Floc's Impact on EBPR Removal Efficiency P UPTAKE......
Floc’s Impact on EBPR Removal Efficiency – **P UPTAKE**

- Adequate (Proper) D.O. (ORP) necessary
  - Not TOO Much
  - Not Too little

- D.O. set point relative to MLSS or SRT
  - mg MLSS/mg D.O. ratio
  - See D.O. Control
Floc Oxygen

Aerobic Layer Similar D.O. to measured D.O.

Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.
mg MLSS/mg D.O. = 900

- Aerobic Layer Similar D.O. to measured D.O.
- Anoxic Layer D.O. diminished from measured D.O.
- Anoxic to Anaerobic Layer Little to NO D.O.
- Low mg MLSS/mg D.O. are smaller floc – lower MLSS concentrations
mg MLSS/mg D.O. = 1,200

Aerobic Layer Similar D.O. to measured D.O.

Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.
mg MLSS/mg D.O. = 2,500

Aerobic Layer Similar D.O. to measured D.O.

Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.

mg MLSS/mg D.O. generally goes up a you INCREASE the MLSS concentration and the floc get bigger

Plays into AN ORP
mg MLSS/mg D.O. vs. Eff. TP

Alum used at anytime in eff.?
Please NOTE is remarks

mg MLSS/mg D.O. vs. Eff. TP
Info on mg MLSS/mg D.O.

1. To Increase the ratio
   A. Increase MLSS
   B. Decrease D.O.
   C. Or Both

2. To Decrease the ratio
   A. Decrease MLSS
   B. Increase D.O.
   C. Or Both

3. A high ratio is a floc which is more anoxic/anaerobic

4. A low ratio is a floc which is more aerobic if not all aerobic
Calculating mg MLSS/mg D.O.

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<td>D.O. setpoint, mg/l</td>
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Calculated mg MLSS/mg D.O. = 781

MLSS mg/l divided by D.O. setpoint = mg MLSS/mg
# Table to Estimate D.O. Setpoint

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**Find Your Sweet Spot**

Still Experiment Summer/Winter Maybe each have its own setpoint
Floc’s Impact on EBPR Removal Efficiency Effluent TSS
Floc’s Impact on EBPR Removal Efficiency – **EFFLUENT TSS**

- **Theory still trialing** – D.O. Setpoint based on MLSS
  - mg MLSS/mg D.O. ratio
    - *Ratio too high* – drive ORP up in AN zone
    - *TOO low* – create too much anoxic or anaerobic condition in floc
  - Higher the MLSS – the bigger the floc
    - At High ratios floc becomes TOO anaerobic and breaks – hydrolyzes
  - See “Floc’s Impact on EBPR Removal Efficiency – P Uptake” section for more info on mg MLSS/mg D.O.
Low ORP in AN or AX zones

Low ORP in AN or AX increases fermentation which breaks up the floc (hydrolyzes) – creating very small (fines) pieces of floc
Started Lime - 50#s per day

Decreased MLSS too far

Rain

Frozen

Eff. TSS, mg/L

Eff. pH

- 30 per. Mov. Avg. (Eff. TSS, mg/L)

- 30 per. Mov. Avg. (Eff. pH)
AN/AX zones destroy or weaken Floc
Aerobic Zone (oxygen) and Lime
Rebuild Floc

mg MLSS/mg D.O. vs. Eff TSS
ADDENDUM

--- ORP ---

% AN of (AN to AB Delta)
--- ORP --- % AN of (AN to AB Delta)

1. Formula
   A. %AN ORP of Delta ORP (AN min to AB Max)

2. The logic behind looking and tracking this – why do it
   A. Create constant biological conditions
   B. DO & ORP are apples and oranges

3. WEF – can have 2 mg/l DO with a – 50 mV or +200 mV
   A. Linden – NH₃-N treatment issue
   B. Flocology – biological logic
      A. Floc dead
      B. More AN zone – less AB - drawing
Why does Eff P increase? Too much fermentation – breaking up floc – make excess sNRP.
Marshfield

ORP – % AN zone of Delta – Eff TP

Still Experimental

High D.O.

%AN of Delta (ABS(AN)+AB)

Eff. TP, lbs/day

21 per. Mov. Avg. (%AN of Delta (ABS(AN)+AB))   21 per. Mov. Avg. (Eff. TP, lbs/day)
Eleva- Strum

ORP – AN & AB Zone & Delta – Eff tRP

ORP, mV

0

100

200

300

400

Eff. tRP, mg/l (Hach)

0

0.05

0.1

0.15

0.2

0.25

0.3

0.35

0.4

ORP AN-2

ORP

AB-3

HACH Eff. PO4-P, mg/l

30 per. Mov. Avg. (ORP AN-2)

30 per. Mov. Avg. (ORP AB-3)
Eleva- Strum

ORP – AN & AB Zone & Delta – Eff tRP

HIGH %AN of Delta

CSWEA Phosphorus/Nutrient Operations

ORP AN-2  ORP  AB-3  HACH Eff. PO4-P, mg/l  30 per. Mov. Avg. (ORP AN-2)  30 per. Mov. Avg. (ORP AB-3)
Eleva-Strum

ORP – % AN zone of Delta – Eff TP

% AN ORP of Delta (AB to AN)

Still Experimental

Power failure & mixer issue

1/1/16 Fri
3/1/16
5/1/16
7/1/16
9/1/16
11/1/16
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
1/1/19

%AB of ORP Delta (AN-AB)

Eff. TP, mg/l

30 per. Mov. Avg. (%AB of ORP Delta (AN-AB))
30 per. Mov. Avg. (Eff. TP, mg/l)
Thank Ya’ll

Op2Myz, LLC
Greg Paul

www.op2myz.com