Convert Activated Sludge to BPR

By Greg Paul and Tim Pernsteiner
Medford WWTP
Before Any Changes in Operation
Design as Chemical Removal
**Ferric Chloride Performance/Effluent TP**

- **2009 to 2014 Average Eff. TP**: 0.760 mg/l
- **2012 to 2014 - Ferric Chloride Annual Average**: 13,333 gallons
  - Daily Average: 36.5 gpd

![Graph showing Ferric Chloride Performance/Effluent TP]
Nutrient Removal Plan Suggestion

Influent Lift Station → AN-1 → AB-1 → AB-2 → AB-3 → AB-4 → FC

Trial Reduced aeration in first Cell to Create Anaerobic Condition Necessary for BPR
Results of **Initial** Reduction in Air to Cell #1

**Chemical Treatment ONLY**

1st Air turned down Cell #1
Improve Bio-P Performance by Getting to Know the System

• Added online monitoring to better understand and track system performance
  – Soluble reactive phosphorus
  – ORP
  – D.O.
Eff. Ortho-P Online Analyzer
Trial Location
Eff. Ortho-P Online Analyzer
ORP Online Monitor
D.O. Online Monitor
INITIAL ASSESSMENT
DEC 2014
BNR Assessment

• Items covered in Assessment
  – PO$_4$-P Profile, mg/l and Mass
  – NO$_3$-N, mg/l and Mass
  – Side stream
  – ORP Data

• Initial Assessment in Dec 2014
• Use Info./Data to help Optimize BNR
P-Optimization

• Assessment shown NEED for ↓ ORP in AN zone
  – COMPLETED-Initial air flow turn down in Cell #1
  – REDUCED AIR FLOW to Cell #1 even more
  – Investigate Possibility to having two Cells as AN zones
  – Decrease overall air flow to aeration tanks
• Learning Operational Controls; D.O., Ferric, SRT/MLSS and RAS
• Evaluate BOD Loadings/BOD:TP
• Bench tested Alum vs. Ferric for backup treatment
• Tracking Fractions of P
• Double check side streams impact
FEB TO MAY 2015
- ADDITIONAL REDUCED AIR FLOW RATE IN AN ZONE
- ASSESSMENT RE-CHECK
Reduced Air Flow Again in Cell #1

Dec - 2014

Apr - 2015
PO$_4$-P Profile, mg/l

<table>
<thead>
<tr>
<th>Location</th>
<th>12/2/14 11:45 AM</th>
<th>4/2/15 12:15 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inf</td>
<td>3.651</td>
<td>2.836</td>
</tr>
<tr>
<td>AN-1</td>
<td>6.390</td>
<td></td>
</tr>
<tr>
<td>AB-1</td>
<td>1.487</td>
<td>1.219</td>
</tr>
<tr>
<td>AB-2</td>
<td>1.532</td>
<td>0.352</td>
</tr>
<tr>
<td>AB-3</td>
<td>1.637</td>
<td>0.196</td>
</tr>
<tr>
<td>AB-4</td>
<td>1.656</td>
<td>0.186</td>
</tr>
<tr>
<td>Fin Clar S</td>
<td>1.024</td>
<td>0.332</td>
</tr>
<tr>
<td>RAS</td>
<td>1.421</td>
<td>0.707</td>
</tr>
</tbody>
</table>
Zero NO$_3$-N in AN-1 is normal for a well operating anaerobic zone.
Average ORP: 5 mV

POOR Anaerobic Conditions
More Anoxic

ORP - Profile

Final Reading AM
Final Reading PM
During **December 2014** Assessment

Avg. ORP was **5 mV**

**In March 2015** with reduced air ORP is **-138 mV**
Results of 2nd Reduction in Air Flow to Cell #1

It appears an additional reason for DECREASED Eff. TP is the HIGH Industrial BOD loadings FEB through JUN.
JUN TO JUL 2015
EXPANDING AN ZONE
FOR INCREASED BPR PERFORMANCE
Expanding AN? - Being Cautious

• Convert Cell #2 to a second Anaerobic Zone
• Watch and checked NH$_3$-N removal efficiency of system during switch over
• Check NO$_3$-N development
Converted Cell #2 to Anaerobic Zone
NH₃-N/NO₃-N in System

<table>
<thead>
<tr>
<th>Sample</th>
<th>6/23/15 NO₃-N</th>
<th>6/23/15 NH₃-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inf</td>
<td>0.916</td>
<td>19.1</td>
</tr>
<tr>
<td>AN-1</td>
<td>0.17</td>
<td>15.3</td>
</tr>
<tr>
<td>AN-2</td>
<td>0.182</td>
<td>12.1</td>
</tr>
<tr>
<td>AB-1</td>
<td>0.663</td>
<td>11.6</td>
</tr>
<tr>
<td>AB-2</td>
<td>6.37</td>
<td>5.8</td>
</tr>
<tr>
<td>AB-3</td>
<td>10.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Results Expanding AN Zone - Cell #1 & #2

- Before anything
- Reduce Air Flow Cell #1
- Reduce Air Flow More Cell #1
- Expand AN Zone to Cell #1 & #2 (1)

(1) Operational issue drove results higher

- Avg. Ferric Chloride Feed, gpd
- Avg. Eff. TP, mg/l
Effluent $\text{PO}_4$-$\text{P}$ Inline Analyzer - Daily Avg
Unit Samples Every 15 minutes (94 times/day)

5-14-15
Turned air down in cell #2 Creating 2$^{nd}$ AN Zones

7-31-15 NOT included because of operational issues - 2.37 mg/l

System Responded Nicely
AUG TO OCT 2015
LEARNING D.O. CONTROL
Learning D.O. Control

Cell #5 Aeration Tank D.O. ppm

125 HP Blower - NO change in air distribution

6-28-15
200 HP Blower

7-29-15
125 HP Blower

9-11-15
Change in air distribution to High at head end and lower at tail

D.O. ppm

Aeration D.O. ppm
Learning D.O. Control - ORP

7-28/7-29
Air to AN#2 turned down to match AN# 1
Switched from 200hp to 125 HP blower

Much MORE to Learn!!!
Remember – this is a manual D.O. System
Results – Reduce Air Flow
Shift D.O. High/Head – Lower/Tail

Before anything

Reduce Air Flow Cell #1
Reduce Air Flow More Cell #1
Expand AN Zone to Cell #1 & #2 (1)
Turned air down in aeration basin 200 to 125 HP and Shift D.O. – More in 1st Aeration Tank - Less Tail (1)

(1) Operational issue drove results higher

- Avg. Ferric Chloride Feed, gpd
- Avg. Eff. TP, mg/l
NOV TO DEC 2015
LEARNING FERRIC CONTROL
Learning Ferric Control – Close Up

Ferric, gpd
Eff. sRP (PO4-P), mg/l
7 per. Mov. Avg. (Eff. sRP (PO4-P), mg/l)
Results – Reduced Ferric Feed

- Reduced Ferric Feed
- Turned air down in aeration basin 200 to 125 HP and Shift D.O. - More in 1st Aeration Tank - Less Tail
- Expand AN Zone to Cell #1 & #2 (1)
- More Cell #1

(1) Operational issue drove results higher
JAN TO APR 2016
LEARNING CONTROL
- SRT/MLSS
- RAS
Learning Solids Control - SRT vs. MLSS

- SRT – did not fit (Solids not counted)
- MLSS – fit
- Still more on work what are best MLSS levels
  –Winter/Summer
Learning RAS Control

• Work on figuring out right blanket level

• RAS too high - Blanket SRT too short
  – Real problem with low MLSS
    • *Little or no final clarifier (FC) blanket*
  – Higher ORP and NO$_3$-N in RAS going into AN zone
  – May be effect FC D.O.

• RAS too low - Blanket SRT too long
  – Low FC D.O.
  – Deal with secondary P-release in final clarifier
RAS as % of Influent vs. Eff. sRP

Much MORE to Learn!!!
Results – MLSS/RAS Control

Before anything
Reduce Air Flow Cell #1
Reduce Air Flow More Cell #1
Expand AN Zone to Cell #1 & #2
Turned air down in aeration basin 200 to 125 HP and Shift D.O. - More in 1st Aeration Tank - Less Tail (1)
Reduced Ferric Feed
Increasing MLSS and Reduce RAS to recover over wasting end of Dec......

(1) Operational issue drove results higher

Avg. Ferric Chloride Feed, gpd
Avg. Eff. TP, mg/l
MAY TO AUG 2016
LEARNING CONTROL
FINAL CLARIFIER D.O.
D.O. TAIL AERATION
RAS FLOW RATE
What Happened???

High due to one day operational controllable issues

VERY little ferric used in highlight period. Started ferric back up in August
Spiking Soluble Eff. Reactive P
Possible Issues

• Change in influent BOD loading – local food processor discharge
• What Does ORP Look Like?
• Can Manipulating the Follow Improve Performance
  – RAS Flow
  – SRT/MLSS
  – D.O. (Manual – NOT Auto controlled)
Spiking Soluble Reactive P
Eff. Analyzer Daily Average

![Graph showing daily spiking soluble reactive P levels from May 2 to August 20, 2016. The levels vary significantly with a notable increase towards the end of the period.]
Close up – Beginning of the Week
And Daily Spiking
CHANGE IN INFLUENT BOD LOADING LOCAL FOOD PROCESSOR DISCHARGE REVIEW

(1) Total BOD Loading, lbs./week & Weekly Avg. of BOD:TP to Eff. TP

(2) Average Weekday & Weekend BOD, lbs./day to Eff. TP
Local Food Processor
All BOD Data (2014-2016)

Variability in Loading

Food Processor BOD, lbs./day
60 per. Mov. Avg. (Food Processor BOD, lbs./day)
Weekly Avg. Eff. TP, mg/l

Weekly Avg. BOD:TP, X 10

Weekly Avg. Eff. TP, mg/l

Total BOD, lbs./week

7 per. Mov. Avg. (Total BOD, lbs./week)

7 per. Mov. Avg. (BOD:TP, Weekly Avg. X by 10)

7 per. Mov. Avg. (Eff. TP, Weekly Avg, mg/l)
BOD Loading up – Eff. TP down
BOD Loading down – Eff. TP up

7 per. Mov. Avg. (Total BOD, lbs./week)
7 per. Mov. Avg. (Eff. TP, Weekly Avg, mg/l)
BOD Loading up – Eff. TP down
BOD Loading down – Eff. TP up
Also
BOD:TP high – Eff. TP low
BOD:TP low – Eff. TP high

What ABOUT
Weekday vs. Weekend
Local Food Processor

BOD - Weekday vs. Weekend vs. Eff. TP

**Weekend (S-S), BOD, lbs./day**

**Weekday (M-F), BOD, lbs./day**

**Eff. TP, mg/l**

---

30 per. Mov. Avg. (Weekend (S-S), BOD, lbs./day)

30 per. Mov. Avg. (Weekday (M-F), BOD, lbs./day)

30 per. Mov. Avg. (Eff. TP, mg/l)
Local Food Processor
BOD - Weekday vs. Weekend vs. Eff. TP

When Black & Red gets far apart there is a big difference between weekday & weekend BOD Loadings.
Lower both Black & Red are the lower the overall BOD loading.
ORP was higher in Mar./Apr. with BETTER sRP ???

First you get the ORP spike then the sRP follows.
AN-1 Zone ORP vs. Eff. sRP - Hourly

May 21st - Saturday

PHB and Glycogen RESERVES in the PAO cells get used up
What is Impact of SRT??
Maybe better than MLSS

SRT vs. Eff. TP

SRT TOO High -
When increased wasting Eff. TP
Dropped

Went TOO High with SRT
Again - Eff. TP went back up
ALSO LOW BOD Loadings

7 Day Moving Avg. of SRT, days
Eff TP, mg/l
7 per. Mov. Avg. (Eff TP, mg/l)
Did every time the RAS rate is increased did it temporarily bump the Eff. TP? Then when the rate is leveled off the Eff. TP goes to about 0.2 to 0.24 mg/l?
Cell #5 D.O. and Eff. TSS (Feb-15 to Jun-16)

Looked a variety of D.O. issues including;
As Aeration Tank D.O. drops does it affect Eff. TSS, performance of eff. sand filtration??
Learning How to Make the BEST Music with the EBRP Orchestra
Sand Filter Operation

• Eff. TSS contains phosphorus – HOW do you improve Filter Performance
• Chemical Treat Sand Filter More Often
• Backwashed more often
• History shows SRT/MLSS concentrations impact Eff. TSS ---
  – Question is there a way to overcome that impact by the way the filter is operated?
• Reduce Improve Eff. TSS – Check with Graph Eff. TSS
Eff. TSS

TSS, mg/l

Date
2/1/15 Sun 3/1/15 Sun 4/1/15 Sun 5/1/15 Fri 6/1/15 Mon 7/1/15 Wed 8/1/15 Sat 9/1/15 Sun 10/1/15 Mon 11/1/15 Tue 12/1/15 Wed 1/1/16 Thu 2/1/16 Fri 3/1/16 Mon 4/1/16 Tue 5/1/16 Fri 6/1/16 Sun 7/1/16 Wed 8/1/16 Mon
Results of Declining Inf. BOD

(1) Operational issue drove results higher

- Reduce Air Flow Cell #1
- Reduce Air Flow MORE Cell #1
- Expand AN Zone to Cell #1 & #2
- Turned air down in aeration basin 200 to 125 HP and Shift D.O. - More in 1st Aeration Tank - Less Tail (1)
- Reduced Ferric Feed
- Increasing MLSS and Reduce RAS to recover over wasting end of Dec
- Eff TP on the RISE - Evaluate Cause BOD Influent Loading/SRT/RAS/D.O.
DURING LAST YEAR & A HALF
BENCH TEST CHEMICALS
FRACTIONS OF P
RECYCLE SIDE STREAMS
Checking out Alum & Ferric

• Bench trial alum vs. ferric

• Results
  – Ferric was more cost efficient than alum in the simulated locations checked
  – Dosing influent may require more than expected due to $\text{H}_2\text{S}$
Tracking Fractions of P

Lowest Results, mg/l:
1-22 – sNRP – 0.012
11-11 – sRP – 0.024
9-8 – pTP – 0.006

Est. Best Case TP - 0.042
Recycle Side Streams

• Low N & P in side stream
  – Unusual – but VERY helpful for BPR

• Why?
  – Well operated aerobic digesters

• NOTE - Heavy Industrial BOD during the dayshift offsets side stream impact
Side Stream - Aerobic Digester

- Digester Filtrate PO4-P, mg/l: 1.695
- Digester Filtrate NO3-N, mg/l: 5.5
- Digester pH, mg/l: 7.70

12-2-14 11:45 AM Tuesday
INCIDENCES Effecting the BPR Performance

- Variable Influent **BOD** Loadings
- **Blower** 125 HP to 200 HP
- **DAF maintenance** shut down
- **Switch** final clarifiers/plugged RAS line
- Power **outage**
- Turning air up to get air flow going again in AN zone
- Turning air up to push through surface **grease** on AN zone
Concluding Thoughts

• BOD(VFAs) are **ESSENTIAL** to achieving very low level of effluent sRP
• Can inline **fermentation** produce enough VFAs to **overcome** limited influent BOD?
• Remember – this is an EXTENDED AERATION system not CONVENTIONAL ACTIVATED SLUDGE system.
• RAS/D.O./SRT Play their Role
• Optimization **tactics will change** somewhat with mixers in anaerobic zone vs. inefficient & minimal controllable air mixing
Fine & Coarse Adjustment

EBPR ADJUSTMENTS

Coarse Control:
BOD:TP
Truly Anaerobic
Inline Fermentation

Fine Control:
SRT*/RAS/D.O.

Work in progress
P.S. - Medford’s **Big Advantages** in Converting to BPR

- Long **narrow** tanks
- **High** Industrial BOD loadings
- **Coarse** bubble diffusers
- Very friendly **side streams** – low in N & P

**THANK YOU**

Greg Paul/Op2Myz, LLC -  [greg@op2myz.com](mailto:greg@op2myz.com)
Tim Pernsteiner/Medford WWTP –  (715) 748-4122