

**ABCs OF ORP
IN BPR
OPTIMIZATION**



ABCs of ORP in BPR Optimization

- What is ORP and What is Used to Measure It?
- Testing/Observation/Interviews in the Field
- Best Management Practices to Monitor/Control BNR using ORP
- Another Thing to Check Into

NOTE: AN=Anaerobic AX=Anoxic AB=Aerobic




What is **O**xidation **R**eduction **P**otential

– info from WEF MOP 37

- **O**xidation-**R**eduction **P**otential is a measurement of the ABILITY of a solution to **accept** or **donate** ELECTRONS.

+ **Positive ORP** Value indicates the ability to **ACCEPT** electrons in an oxidative environment (oxygen present)

- **Negative ORP** Value indicates the ability to **DONATE** electrons in a reductive environment (no oxygen available)



I'm ready to **ACCEPT** electrons. There is lots of room in my dump truck and I'm ready for them

(+) Positive ORP
the Ability to **ACCEPT**
Electrons
(Aerobic Zone)
Oxidation Potential

I've have lots of electrons ready to **DONATE** to whoever can use them, where do you want them dumped



(-) Negative ORP
the Ability to **DONATE**
Electrons
(Anaerobic Zone)
Reduction Potential

What is Used to Measure ORP?

ORP Meter

- Stationary, portable and handheld/pen style
- Hach, Insite, ABB, Oakton, YSI units and Others



Using an ORP Meter

'%\$###*!@ @#\$

FROM YSI - TIPS, CAUTIONS AND LIMITATIONS

- Although based on relatively simple theory, ORP is, **unfortunately**, also a measurement that can show more problems than other water quality sensors with regard to consistency between different instruments and overall accuracy.



Using an ORP Meter

'%\$##*!@ @#\$

FROM YSI - TIPS, CAUTIONS AND LIMITATIONS

- ORP sensors can show a slow response in environmental water if the platinum button of the probe has been **contaminated** with extraneous material. Common contaminants include hard water deposits, **oil/grease, or other organic matter.**



Using an ORP Meter

'%\$##*!@ @#\$

FROM HACH - INTRODUCTION TO OXIDATION REDUCTION POTENTIAL MEASUREMENT

- ORP measurement readings occur slowly compared to pH measurements. While a pH value can be obtained within seconds, a stable ORP value **can take up to several minutes, if not hours**, to reach the final equilibrium due to the type of reactions and their reaction rates. Example Linden

Learn how to use ORP
Meters correctly – Read
O&M manual that comes
with unit – **BUT** keep in
mind the tips from above

WEF Manual of Practice No. 37

ORP Meter Information

Principle of Operations

Installation

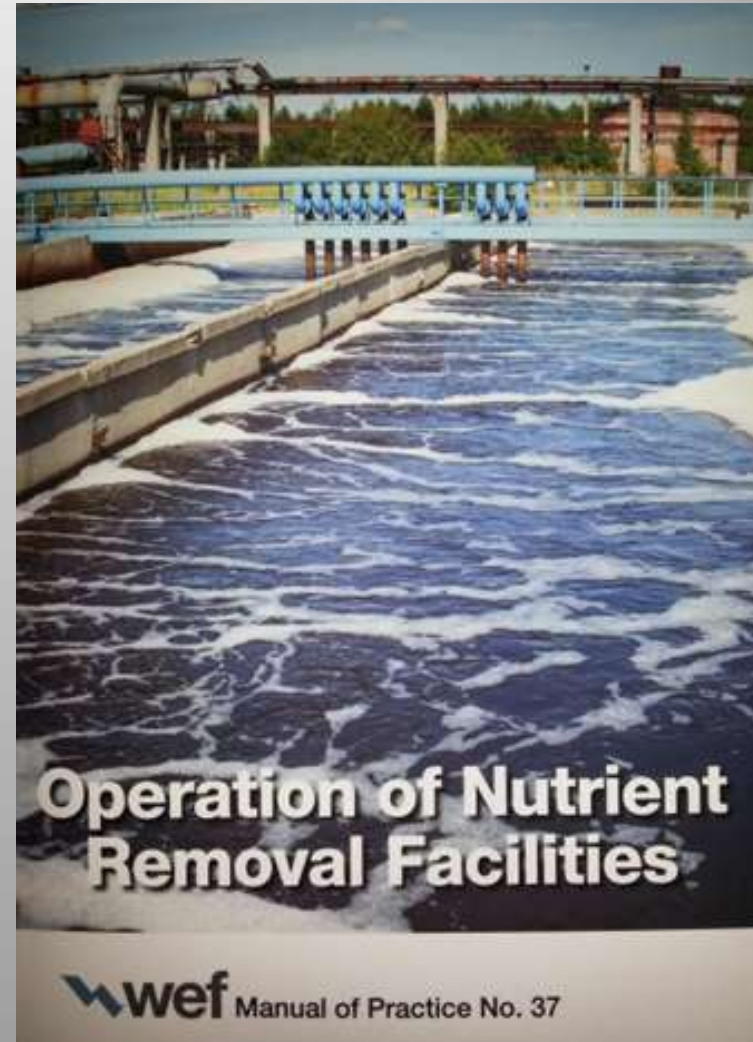
Concerns

Drifting & Fouling

Accuracy & Repeatability

Cleaning & Maintenance

Requirements



Field Testing/Observation/Interviews

INCLUDED 26 BNR SYSTEMS - Researching Proper Application of QLF EnhanceBio^{P+N}©

- WI/MN/IL/AR/VA
- WWTP flows ranged from 20,000 gpd to 40 MGD

Field Testing/Observation/Interviews

12 TYPES OF BNR SYSTEMS

- AO/Modified AO/Modified AO with separate fermenter
- Orbital Ditch NO separate AN zone
- Oxidation Ditch with separate AN zone
- FluidDyne SBR
- A2O/A2O with separate fermenters
- 5 Stage Bardenpho
- Johannesburg
- 2 Oxidation Ditches run in series with separate AN & AX zones
- One unknown unique design.



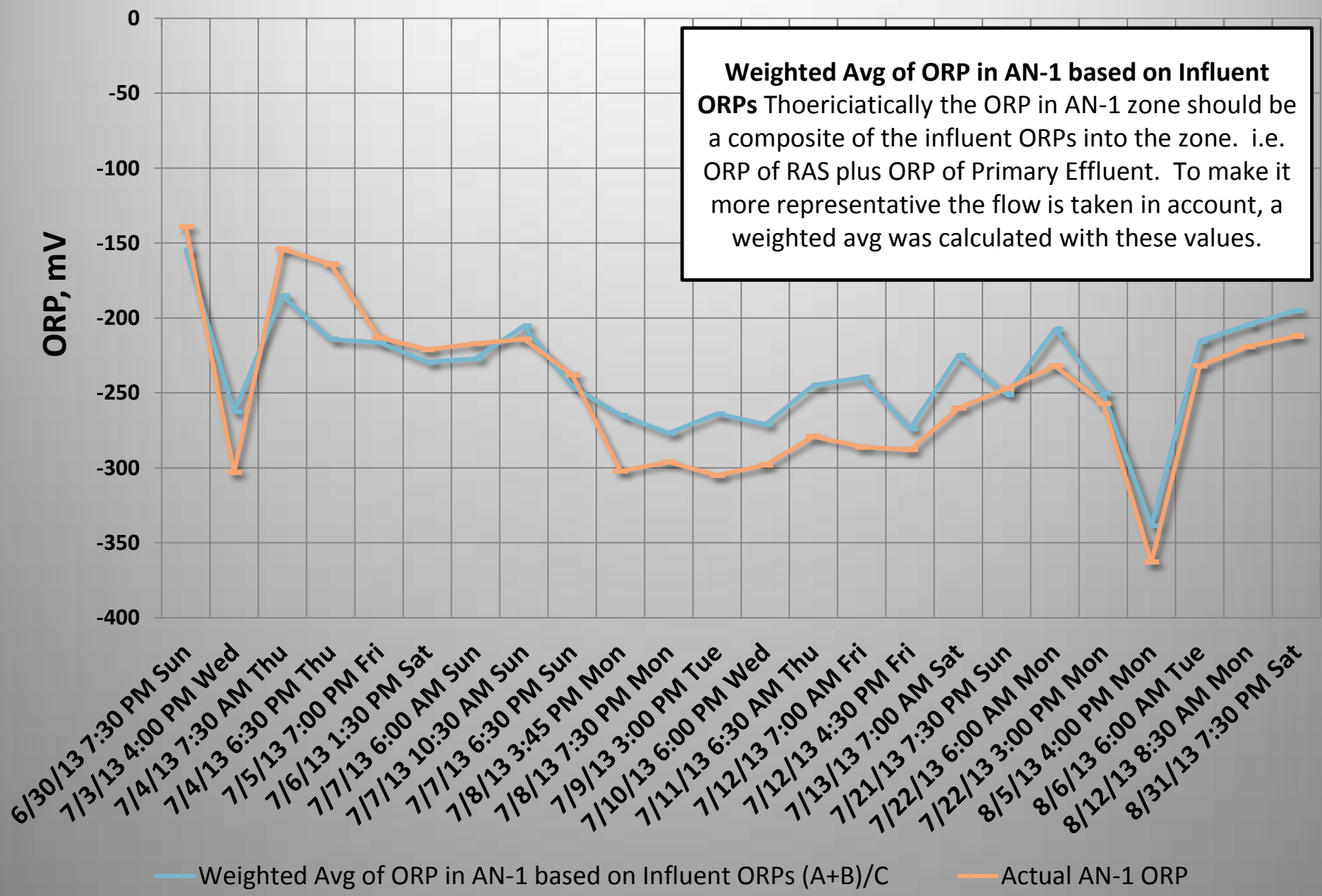
Field Testing/Observation/Interviews

BOTH BIOLOGY AND PHYSICAL INPUTS CAN CHANGE ORP

- Mass balance of ORP – weighted average of inputs
 - Base ORP of AN zone is a combination of influent sewage ORP and RAS ORP
- BOD loading and detention time in basin also effects ORP

LaCrosse - Weighted Average of ORP into AN Zone vs. Actual ORP

Weighted Avg of ORP in AN-1 based on Influent ORPs
 Thoericiatically the ORP in AN-1 zone should be a composite of the influent ORPs into the zone. i.e. ORP of RAS plus ORP of Primary Effluent. To make it more representative the flow is taken in account, a weighted avg was calculated with these values.





Field Testing/Observation/Interviews

LOWER OVERALL SYSTEM ORP

- If sludge in a BNR system is exposed to a GREAT DEAL of AN conditions, by designed or operations, that will result in overall lower ORP
- The higher the MLSS concentration -> lower the overall system ORP will be.
- AB zone may have negative ORP even with a healthy D.O. - 3 to 5 ppm,
- Linden very low AN - ORP -390mV (Dropped like a Rock) and AB -175mV

Field Testing/Observation/Interviews

**ONCE SLUDGE LEAVE AB ZONE ORP CAN
START DROPPING AS RESIDUAL OXYGEN IS
USED UP**

The speed at which ORP drops appears to be relative to how low the **overall ORP is** in the system – Concerns:

Channel to Final Clarifiers

Secondary P-Release

Needs More Investigate

Field Testing/Observation/Interviews

NITRATE RECYCLE RATE IN A2O SYSTEM TOO LOW

- Turns AX zone into AN zone, extending existing AN zone
- Excess BOD NOW coming out of this extended AN zone (AX) - Nitrifiers in trouble and/or cause filaments, 021N?
- **Needs More Investigation**



Field Testing/Observation/Interviews

USE ORP FOR MONITORING AND/OR CONTROL

- Monitor final clarifier (just above blanket) to prevent secondary P release.
 - Variety RAS flow rate
- Monitor AX zone to prevent from becoming anaerobic
 - Variety nitrate recycle pump



Field Testing/Observation/Interviews

USE ORP FOR MONITORING AND/OR CONTROL

- Monitor AN zone
 - Variety rbCOD supplementary feed
- Monitor AN zone using inline fermentation
 - Variety ON/OFF timer
 - Control with ORP set point

MORE LISTED ITEMS COVER IN BMPs



Field Testing/Observation/Interviews

USE ORP FOR MONITORING AND/OR CONTROL

WWTPs Monitoring/Controlling ORP

- **Fort Atkinson WI** - monitor/partial control AN zone – determine supplement QLF EnhanceBio^{P+N}© feed levels **INLINE**
- **Shawano WI** - (Wolf Wastewater Treatment Plant) Control RAS/monitor AN zone **PORTABLE** and **INLINE**
- **Janesville WI** - Monitor AX & AN zones **INLINE**



Field Testing/Observation/Interviews

USE ORP FOR MONITORING AND/OR CONTROL

WWTPs Monitoring/Controlling ORP

- **LCDPW Mill Creek IL** - control AX & AN zones control inline fermentation in both. **INLINE**
- **LaCrosse WI** - monitor AN, AX and AB zones **INLINE** and **PORTABLE**
- **Northern International University** – AX zone monitor ORP and manually adjust QLF EnhanceBio^{P+N}© feeding according **INLINE**
- **Eleva-Strum WI** – Monitor AN, AX and AB zones **PORTABLE**

Best Management Practices to Monitor/Control BNR using ORP

- Why Management and Control of ORP Level in BNR System?
- Choosing the a Suitable Meter
- Doing system survey.
- What ORP Range Should I Use for My Process?
- Operational Practices to Rise & Lower ORP
- Establishing Optimal ORP



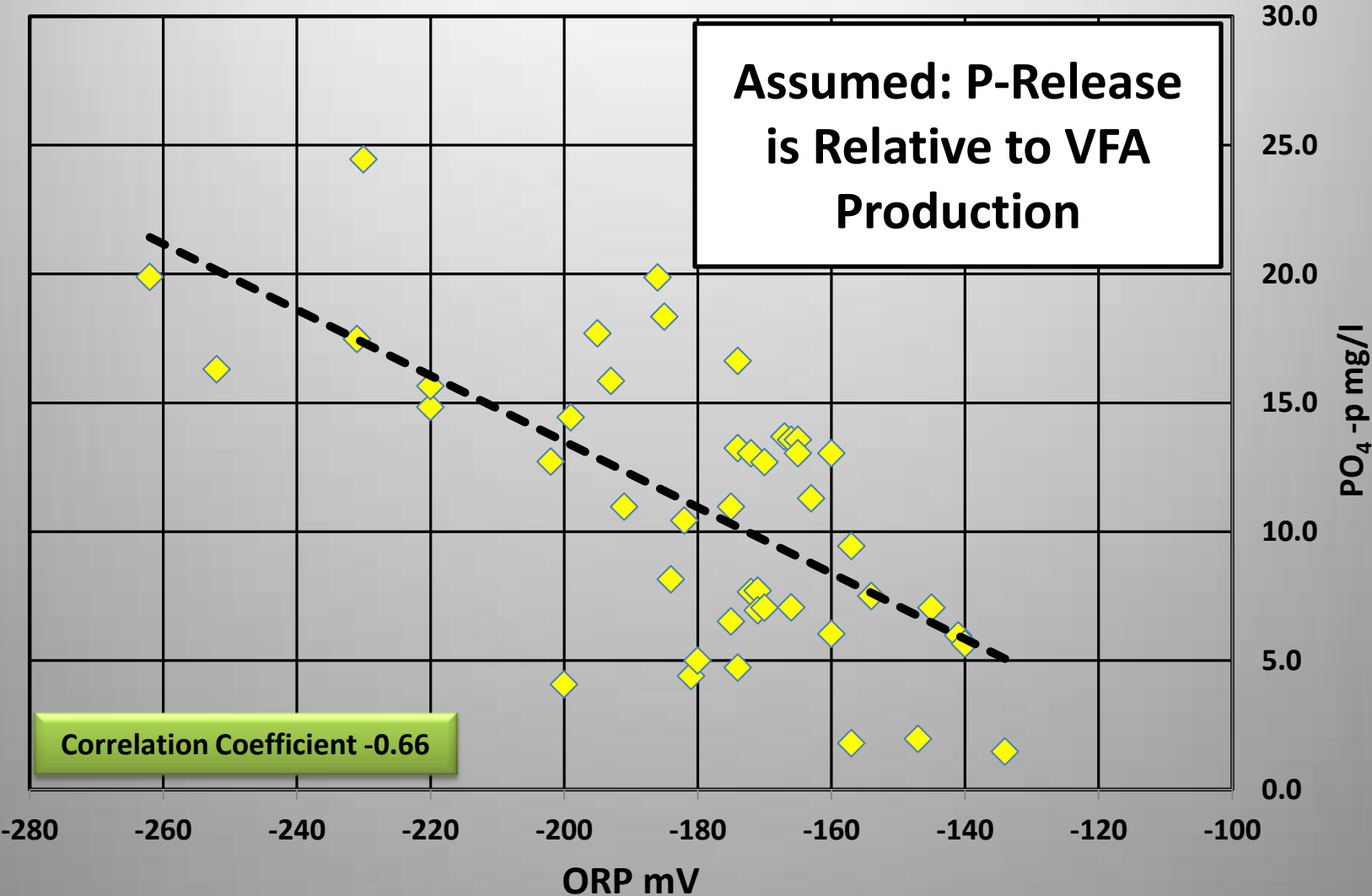
Why Management and Control ORP Levels in BNR System

BPR NEEDS ADEQUATE VFA

7 TO 10 LB. OF VFAS TO REMOVAL A LB. OF P

- If AN zone ORP is too high you won't get proper/adequate rbCOD conversion to VFAs
- If AN zone ORP is too low you waste VFAs to methane formers and potentially over feed AB zone with excess BOD

AN Zones ORP vs. PO₄ - P



Correlation Coefficient -0.66

Assumed: P-Release is Relative to VFA Production

◆ AN Zones PO4 - P - - - Linear (AN Zones PO4 - P)

Why Management and Control ORP Levels in BNR System

ANOXIC ENVIRONMENT REQUIRED TO DRIVE DENITRIFIERS

- If the AX zone ORP is too high you will not get denitrification
- If the AX zone ORP is too low you can create another AN zone and cause

Choosing the a Suitable Meter

What are you looking for

- Trends
- Surveys
- One time measurement?

Choosing the a Suitable Meter

Inline measurement is the best method for constant ORP measurement

- **Gives continuous trend – Invaluable!!**
- **No waiting for achieving probe equilibrium**





Choosing the Correct Meter

Portable – measuring In situ

- Need to let probe stabilize to reach equilibrium.
 - May be as long as 30-45 minutes. Once equilibrium is reached in a solution with a specific level next reading it does not take very long.
 - Every time you switch to a solution with a significantly different ORP level you need to wait for the equilibrium to be achieved.
- Good economical method for surveying various WWTP locations



Choosing the a Suitable Meter

Handheld/Pen Style

- Equilibrium issue as above
- Ok for surveying various WWTP locations



Doing System Survey

Survey/Document ORP of your BNR
influent flow streams.

Then review these influent streams to
see if there are ways to **change** the
ORP for any of these streams.

Make the changes and re-check ORP.

What ORP Range Should I Use for My Process?

- Use Biochemical Reactions & Corresponding ORP Value Table as a reference
- Info From: Florida Rural Water Associate/WEF
WE&T/YSI/Hach/WEF/MPCA BNR
- Keep in MIND these are GUIDELINES – NOT GOSPEL

| Florida Rural Water Associate | ORP, mV | YSI | ORP, mV | Hach | ORP, mV |
|-------------------------------|--------------|---|--------------|------------------------|--------------|
| Organic Carbon Oxidation | +50 to +225 | cBOD degradation with free molecular oxygen | +50 to +250 | | |
| Polyphosphate Development | 0 to +250 | Biological phosphorus removal | +25 to 250 | | |
| Nitrification | +100 to +350 | Nitrification | +100 to +350 | | |
| Denitrification | -50 to +50 | Denitrification | -50 to +50 | | |
| Polyphosphate Breakdown | -25 to -200 | Biological phosphorus release | -100 to -250 | | |
| Sulfide Formation | -50 to -250 | Sulfide(H ₂ S) formation | -50 to -250 | | |
| Acid Formation | -100 to -225 | Acid formation (fermentation) | -100 to -225 | Reduction of sulfates | +100 to -200 |
| Methane Formation | -200 to -350 | Methane production | -175 to -400 | Development of methane | -150 to -280 |

| WEF WE&T Jan '13 | ORP, mV | WEF MOP-30 | ORP, mV | MPCA-Biological Nutrient Removal | ORP, mV |
|---------------------------------------|--------------|---|----------------|---|----------------|
| Carbon oxidation (cBOD stabilization) | +50 to +200 | | | Aerobic (oxic) | +50 to +200 |
| Polyphosphate accumulation | +50 to +250 | | | | |
| Nitrification | +150 to +350 | | | | |
| Denitrification | -50 to +50 | | | Anoxic - little or no oxygen, just nitrates | +50 to -200 |
| Polyphosphate release | -40 to -175 | | | | |
| Sulfide(H ₂ S) formation | -50 to -250 | | | | |
| Acid formation (fermentation) | -40 to -200 | Acid-forming bacteria proliferate | -300 | Anaerobic - No nitrate, no oxygen present | Less than -300 |
| Methane production | -200 to -400 | Methanogenesis onset which can adversely affect VFA | Less Than -600 | | |

Operational Practices which Cause ORP to Rise

- Any natural aeration, clarifier weir overflows, any water falling introduces oxygen
- Aerated grit chambers
- Adding alum
- Increasing RAS flow rate – Decreases HRT in AN zones



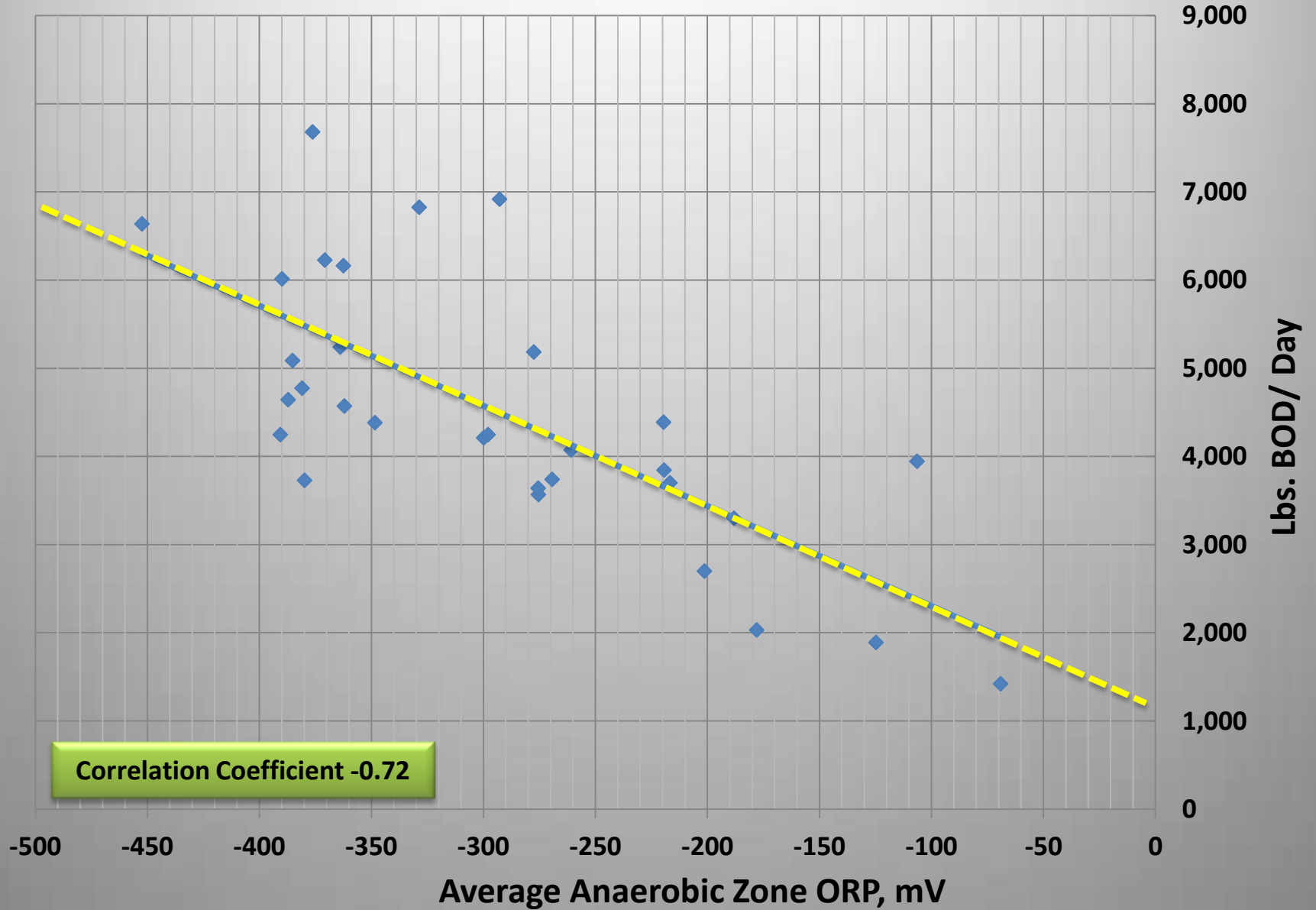
Operational Practices which Cause ORP to Rise

- Shorter HRT drive ORP up
 - High RAS/Low final clarifier blanket
- AN Zone SRT -> Inline fermentation:
Control AN zone mixer with ORP – set point or timers
 - Increase ORP by increasing mixer ON time.

Operational Practices which Cause ORP to Rise

- Increasing AX zone nitrate recycle rate
- Decreasing SRT or MLSS
- High nitrates being recycled in RAS
- Low BOD Loadings drives ORP up

Fort Atkinson WWTP - Compare ORP to BNR Influent BOD Loading





Operation Practices which Cause ORP to Lower

- Decreasing RAS flow rate – increases HRT in AN zones
- Longer HRT drive ORP down
 - High final clarifier blanket
 - Reduces ORP & increase denitrification
 - CAUTION – floating sludge and secondary P-release



Operation Practices which Cause ORP to Lower

- AN Zone SRT -> Inline fermentation: Control AN zone mixer with ORP – set point or timers
 - Lower ORP by increasing mixer OFF time.
- Decreasing AX zone nitrate recycle rate
- Increasing SRT or MLSS
- Low or NO nitrates being recycled in RAS



Operation Practices which Cause ORP to Lower

High BOD Loadings drives ORP down

Example: QLF EnhanceBio^{P+N}© Effects ORP

- NIU rbCOD addition needed for TN during Student Break (Very Low Flow/Loading)
- Issue – Orbital Ditch AX zone maintained at approx. -200 mV due to pump failure ORP rose to -100 mV
- Poured 2 gallons in AX zone all at once and ORP dropped back down to -200 mv in about a ½ hour.
- 2 gallons was the daily dose usually metered in all day long

Establish your BNR optimal
ORP operating levels by
experience

Another Thing to Check Into

- Remember biology and chemistry happen at the floc level too
 - Floc has aerobic/anaerobic ZONES, inside/outside of the floc
 - Ox Ditches & Extended Air Systems???
 - How can we use ORP under these conditions?

That's All Folks

- Understand what ORP is and the ORP Meter limitations
 - ORP Data is **Invaluable** for BNR System Operation
 - Take in account the meter limitations when deciding whether to get an inline, portable or handheld/pen type unit.
- Sludge age, Detention Time, Nitrates, Oxygen and BOD Loadings all Drive ORP Levels
- Understand and utilize these different operational options you have to drive ORP in the direction that improves your treatment.
 - Think of it like driving, you have controls and gauges you use to safely arrive at your destination

Measuring/Tracking ORP is Essential for optimizing
BNR/BPR

All I Really Need to Know I Learned in Kindergarten

1. Share everything.
2. Play fair.
3. Don't hit people.
4. Put things back where you found them.
5. CLEAN UP YOUR OWN MESS.
6. Don't take things that aren't yours.
7. Say you're SORRY when you HURT somebody.
8. Wash your hands before you eat.
9. FLUSH.
10. Warm cookies and cold milk are good for you.
11. Live a balanced life - learn some and drink some and draw some and paint some and sing and dance and play and work everyday some.
12. Take a nap every afternoon.
13. When you go out into the world, watch out for traffic, hold hands, and stick together.
14. Be aware of wonder. Remember the little seed in the Styrofoam cup: The roots go down and the plant goes up and nobody really knows how or why, but we are all like that.
15. Goldfish and hamster and white mice and even the little seed in the Styrofoam cup - they all die. So do we.
16. And then remember the Dick-and-Jane books and the first word you learned - the biggest word of all - LOOK."

— Robert Fulghum, All I Really Need to Know I Learned in Kindergarten

QUESTIONS OR COMMENTS

• GREG PAUL

• 608-738-5748

• GREG@OP2MYZ.COM