Advances in On-line Instrumentation for Wastewater Process Control

Justin Irving, P.E
Acknowledgements

Sarah Galst, P.E. (Hazen and Sawyer)

Phill Yi, P.E. (Hazen and Sawyer)

Katya Bilyk, P.E. (Hazen and Sawyer)
Presentation Outline

1. Goals/Considerations

2. Background on Parameters of Interest and Measuring Techniques

3. Case Studies Utilizing Instrumentation and Models
Goals/Considerations
Goals of Monitoring in WWTPs

- Better Understanding
- Advanced Warnings of Problems
- Better Effluent Quality
- Reduced Energy Use
- Reduced Chemical Consumption
- Simplifying Wastewater Treatment
Considerations (High-Level)

• How can this information be used?

• Are staff resources available to adequately maintain the sensors and review the data?

• If cost-savings is a goal, is the overall control strategy going to work?
Considerations (Detailed)

• Can the sensor monitor over the range/accuracy needed?
• How will the location of the sensor impact the measurement?
• If a single sensor is “mission-critical”, should there be redundancy (if so, how much)?
Background
Parameters of Interest

- Dissolved Oxygen
- Temperature
- pH/alkalinity
- Oxidation-Reduction Potential
- Total Suspended Solids
- Flow
- Ammonia
- Nitrate (NO$_x$-N)
- COD/BOD Surrogates
- Phosphorous

Conventional Parameters

“Advanced” Parameters
Dissolved Oxygen

- Amperometric Sensor
  - Low capital costs
  - Higher maintenance
  - Less reliable due to consumables
  - Higher absolute accuracy

- Optical Sensor
  - Higher capital costs ($1 – 2K)
  - Lower maintenance
  - More reliable due to ease of maintenance
  - Lower absolute accuracy
Oxidation Reduction Potential (ORP)

- Measurement of Oxidizing and Reducing Conditions
- Represents State of Process
- Inexpensive, low-maintenance

<table>
<thead>
<tr>
<th>Biochemical activity</th>
<th>Approximate ORP range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon oxidation</td>
<td>+50 to +200</td>
</tr>
<tr>
<td>(carbonaceous biochemical oxygen demand stabilization)</td>
<td></td>
</tr>
<tr>
<td>Polyphosphate accumulation</td>
<td>+50 to +250</td>
</tr>
<tr>
<td>Nitrification</td>
<td>+150 to +350</td>
</tr>
<tr>
<td>Denitrification</td>
<td>-50 to +50</td>
</tr>
<tr>
<td>Polyphosphate release</td>
<td>-40 to -175</td>
</tr>
<tr>
<td>Acid formation</td>
<td>-40 to -200</td>
</tr>
<tr>
<td>Sulfide formation</td>
<td>-50 to -250</td>
</tr>
<tr>
<td>Methane formation</td>
<td>-200 to -400</td>
</tr>
</tbody>
</table>

Courtesy of WET

Courtesy of Hach
Total Suspended Solids

• Many Optical Instruments (Visible/Near-IR) on the Market
• Typically In-situ, bypass available
• Ensure Correct Measuring Range is Selected (Pathlength)
Flow

• Different types of flow measurement devices
• Different devices are suitable for different types of installations
• Always consider the end use of the data (e.g. chemical pacing, simple trending, regulatory reporting)
Ammonia

- In-situ ISE Probes
  - Accuracy/performance varies
  - Require calibration
  - Replacement of electrodes

- Cabinet-type analyzers
  - Accurate
  - Sample filtration and delivery challenging in WWTPs
  - Consumables replacement

Courtesy of WTW

Courtesy of ChemScan
Nitrate (Nitrite?)

- **In-situ ISE Probes**
  - Many MFRs performance varies
  - Often coupled with ammonia ISE
  - Calibration/replacement of electrodes

- **In-situ UV**
  - Utilizes absorbance from 200 – 220 nm
  - Many MFRs
  - Low O&M requirements/costs

- **Cabinet-Type Analyzer**
  - Pump/filter
  - Reagents
  - Accurate
Phosphorous

- Cabinet-Type Analyzer
  - Pump/filter
  - Reagents
  - Accurate
  - Many MFRs, costs vary

Courtesy of ChemScan
Case Study #1

Energy and Chemical Savings Through Ammonia-Based DO Control
Case Study #1 – Background

- Ammonia-based DO control
- Modeled potential savings in energy/chemical

Nitrite-Shunt Reaction Path
Case Study #1 – Background

NH3 level in basin

Airflow

Too much air

Not enough air
Case Study #1 – Background

- Operator selects effluent ammonia setpoint
- Ammonia > setpoint, DO increased
- Ammonia < setpoint, DO decreased
Case Study #1 – Background
Case Study #1 – Process Model

- Process modeling concluded that process air (6%) and carbon (20%) savings *were* possible using an ammonia-based DO control scheme.
Case Study #1 – Process Model

• The ammonia-based DO control scheme relies on accurate ammonia measurement below 1 mg/L (NH3-N)
Case Study #1 – Implementation

- The ammonia sensors located on site were evaluated and could not measure below 1 mg/L with consistent accuracy.
- When automated operations using the ammonia sensors were attempted, process upsets resulted (loss of nitrification)
- **The sensors must be reliable at the level needed for enhanced control**
Case Study #1 – Details

- If NH3-N < 0.75 mg/L
  - DO setpoint in Zone 2, 3 and 4 = 0.3 mg/L
- If NH3-N > 1.0 mg/L
  - DO setpoint in Zone 2, 3 and 4 = 2.0 mg/L
Case Study #1 – Details

According to this graph, the biggest change from previous mode of operation was lowering the DO in the zone that corresponds to approximately 65% of their aerobic volume.

Period of NH3-Based DO Control
3/23/14 – 4/28/14
Case Study #1 – Details

Concentration (mg/L)

Average of AT 4 Zone 3 Ammonia
Average of AT 5 Cell B Nitrate
Average of AT 5 Zone 3 Ammonia
Average of AT 6 Cell B Nitrate
Average of AT 6 Zone 3 Ammonia
Average of AT 7 Zone 3 Ammonia

1/1/2014 - 3/23/2014 Operating in DO Control Mode

5/7/2014 - AT 5 and 7 Ammonia probes online

Operating in Ammonia Based DO Control Mode

Operating in DO Control Mode Until 5/12/2014

Nitrate Drop

Nitrate increase thought to be due to decrease in Aerobic SRT and HRT
Case Study #1 – Next Steps
Case Study #2

Optimizing Carbon Dosing
Case Study #2 – Background

• Five (5) WWTPs where supplemental carbon added to enhance denitrification

• Utilization of nitrate instrumentation to optimize carbon addition rate

• Evaluated different sensor locations and control schemes to determine best ROI (BioWin)
Case Study #2 - Background

- NH3-N load varies significantly throughout the day
- COD/NH3-N ratio also varies throughout the day
Case Study #2 – Dosing Strategy 1

- Flow-paced carbon addition based on influent flow rate
1. Mass-paced carbon addition based on ratio of COD to Nitrate/Nitrite entering the head of Pass D.
Case Study #2 – Dosing Strategy 3

- Feedback trim based on the Nitrate/Nitrite concentration at the end of the Pass D anoxic zone
Case Study #2 – Summary of Results

- Plant A shows that the more sophisticated strategy results in greater savings

<table>
<thead>
<tr>
<th>Plant</th>
<th>Eff TN mg/L</th>
<th>Carbon gpd</th>
<th>Eff TN mg/L</th>
<th>Carbon gpd</th>
<th>Eff TN mg/L</th>
<th>Carbon gpd</th>
<th>% Carbon Savings over Strategy 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>8.9</td>
<td>6,620</td>
<td>8.8</td>
<td>6,270</td>
<td>8.9</td>
<td>5,870</td>
<td>5.3%</td>
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<tr>
<td>Plant B</td>
<td>6.8</td>
<td>2,190</td>
<td>6.8</td>
<td>1,940</td>
<td>n/a</td>
<td>n/a</td>
<td>11.3%</td>
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<tr>
<td>Plant C</td>
<td>8.3</td>
<td>7,910</td>
<td>8.2</td>
<td>7,850</td>
<td>n/a</td>
<td>n/a</td>
<td>0.8%</td>
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<tr>
<td>Plant D</td>
<td>5.2</td>
<td>820</td>
<td>5.2</td>
<td>760</td>
<td>n/a</td>
<td>n/a</td>
<td>7.6%</td>
</tr>
<tr>
<td>Plant E</td>
<td>5.9</td>
<td>4,090</td>
<td>6.0</td>
<td>3,910</td>
<td>n/a</td>
<td>n/a</td>
<td>4.3%</td>
</tr>
</tbody>
</table>
Conclusions

• Instrumentation has clear benefits for advanced WWTP processes

• Understanding goals and considerations up front is essential for success

• Process modeling can help understand the concrete benefits of a control scheme and help the decision-making process
Questions?