Wastewater Nutrient Removal
Advanced Analytical Technology
Wastewater Treatment Requirements

- Efficiently process wastewater that often varies significantly over time in ammonium levels
- Consistently comply with permitted effluent discharge requirements
- Measure and “Control” the aeration/activated sludge process
  - Minimize energy usage through real-time blower control
- Control based on key criteria to ensure process is responding to current ammonium load
  - Dissolved oxygen measurement is a measure of sufficient aeration
  - Compliance can be determined by measuring ammonium and nitrate directly
  - Controlling to defined ammonium levels allows for reduction in blower energy usage
Carbon and Ammonium/ Nitrate Reduction

Reduction of carbon content:

Organic carbon $\xrightarrow{\text{oxygen}} CO_2 + H_2O$

Biological conversion of ammonium/ nitrate content:

Nitrification: $NH_4^+ \xrightarrow{\text{oxygen}} NO_2^- \xrightarrow{\text{oxygen}} NO_3^-$

Denitrification: $NO_3^- + C_{org} \xrightarrow{\text{no oxygen}} N_2$

- The dissolved oxygen (DO) needed for these processes is delivered into the water by energy consuming blower systems.
- Historically time or DO measurement have been used to operate blowers to ensure sufficient oxygen levels are present for proper reduction.
- Today, modern ammonia measurement technology is available and in use to control blowers – dramatically reducing energy usage.
Blower Operation Schemes

- On/Off, manual with no frequency drive control – **High Energy Consumption**

- DO set point control with frequency drive – **Inefficient energy consumption**

- Ammonium set point driving DO control – **Improved energy consumption**

- Ammonium set point with DO high and low set points – **Optimum energy consumption**
Optical Dissolved Oxygen (DO) Sensor

Low Oxygen – High amplitude, long duration fluorescence

High Oxygen – Low amplitude, short duration fluorescence

Exciting Light

Fluorescence

Oxymax COS61D

Liquiline CM442
Grab sample indicates too much NH$_4^+$ in final effluent

Operator begins to manually adjust air

Flow rate

DO set point (0.5 mg/L)
NH₄⁺ Measurement: WWTP - Hanover, PA

Operator begins to manually adjust air
NH₄⁺ in control

Ammonium NH₄⁺
Flow rate
DO set point (0.5 mg/L)
Ion-selective Electrode System

- The compact system consists of a sensor and a transmitter.

- The sensor consists of ion-selective electrodes and a reference electrode which are installed in an immersion assembly with automatic compressed-air cleaning.

- Up to three ion-selective electrodes measure ammonium, nitrate and, where necessary, other ions like potassium or chloride simultaneously.
Measuring Principle: Ion-selective Electrodes

- Potentiometric measurement by means of ion-selective electrodes analogous to pH measurement (high impedance).

- The potential difference (voltage in mV) between reference electrode and ion-selective electrode is measured – it is proportional to the ion concentration.

- The membrane is the ion-selective part of the electrode. Embedded ionophores are selective for the ion to be measured.

- Color and turbidity of the medium do not have an impact on the measured value.
ISEmax Sensor Head

Ammonium electrode with membrane cap

Cleaning unit

Potassium

Nitrate

Dummy electrode

Temperature sensor CTS1

pH electrode CPS11 with Ag/AgCl reference

Potential matching pin

Ammonium

Nitrate

Potassium

Chloride
## Cross Sensitivities

<table>
<thead>
<tr>
<th>Sensor Brands</th>
<th>NH$_4$ vs Potassium</th>
<th>NH$_4$ vs Sodium</th>
<th>NO$_3$ vs Chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endress+Hauser</td>
<td>1:30</td>
<td>1:800</td>
<td>1:300</td>
</tr>
<tr>
<td>Brand Y</td>
<td>1:14</td>
<td>1:800</td>
<td>1:200</td>
</tr>
<tr>
<td>Brand Z</td>
<td>1:11</td>
<td>1:800</td>
<td>1:200</td>
</tr>
</tbody>
</table>

“Potassium is ubiquitous in wastewaters and in some wastewaters is present at several hundred to several thousand mg/L.”

---

Wastewater Energy Savings Case Study

J.D. Phillips Wastewater Reclamation Facility

Colorado Springs, CO
The J.D. Phillips Wastewater Reclamation Facility
The J.D. Phillips Wastewater Reclamation Facility

- Uses a 3-stage activated sludge treatment process
- Designed for the treatment of 20 MGD the actual flow is 8 MGD
- The secondary treatment has three passes
  - A pass is used for phosphorus removal and partial denitrification
  - Passes B & C are used for nitrification
- The plant wants to insure compliance to its varying discharge permit while reducing costs
- Close to customer, causing rapid fluctuations in ammonia
- Desire to run effluent ammonia at 0 mg/L
SCADA View with Control
The J.D. Phillips Wastewater Reclamation Facility

- Due to high ammonia influent concentration and deficiency in BOD it was apparent that the plant needed improvements.
- Low alkalinity created some pH excursions outside the discharge permit.
- Energy usage was high.
- In 2009, a source for additional carbon was found and instruments to measure ammonium, nitrate and pH were installed.
- A step by step analytical measurement and control approach changed the way aeration and denitrification are controlled.
Energy Savings – Nov. 2010 vs. 2009

$ Power Cost

$ November

2009

2010

Energy Cost Decreased
Average Flow – Nov. 2010 vs. 2009

Flow Increased
Diurnal Flow Variations

[Image of a graph showing diurnal flow variations in raw wastewater influent flow calculations. The graph includes time stamps from 9:11:52 PM to 11:15:26 PM on 5/4/2011, with values ranging from 0.00 to 33.00 MGD.]
Diurnal Variations in Ammonia Concentration and Energy

Ammonia Conc. ——— Energy ———

Time ———

Ammonia Conc. (ppm)
PID Loop for DO

- DO Controller
- DO Set Point

Flow → DO Controller → Flow

Flow
ISEmax Installation

Ion-selective Sensor

Transmitter
PID for DO with Ammonium Cascade

DO Controller

DO Set Point

NH₃ Controller

NH₃ Set Point

Flow

Slide 23 / 58
B Pass PID Blower Control for NH₃

High and Low limits on DO

NH₃ Controller

NH₃ Set Point

Flow

Smaller blower

Flow
Analytical Measurement Points

Primary Influent

NH₄, NO₃

DO

NH₄, pH

NO₃, pH

Swing Zone
Anoxic Zone
Anaerobic Selector
A-Pass

B-Pass
Influent Channel

C-Pass
SCADA View with Control
B Pass PID Blower Control for NH₃

Ammonia Conc.  Set point  DO Value
Changes in Ammonia Concentrations
Influent and Effluent – 2010 vs. 2009

![Graph showing changes in ammonia concentrations in influent and effluent from 2009 to 2010. The graph includes lines for Eff Ammonia-2009, Inf Ammonia-2009, Eff Ammonia-2010, and Inf Ammonia-2010, with annotated limits on the y-axis.]
Changes in Influent Flow – 2009 vs. 2010
Overall reduction in power required to remove NH$_3$. 
Average Power Required for NH$_3$ Removal

KW/MGD/NH$_3$ removed

- 2009: 1.6
- 2010: 1.2
Overall Power Consumption

- Peak Consumption:
  - 2009: [Value]
  - 2010: [Value]

- Off Peak:
  - 2009: [Value]
  - 2010: [Value]
Summary

- Wastewater content can vary unpredictably in nitrogen, organic carbon and phosphates.
- It can be difficult to comply with discharge permit requirements without “over-controlling” the process.
- Using analytical instrumentation and control in the activated sludge treatment process can improve control and reduce operating costs.
- DO measurement may not be the ideal method for blower control.
- Direct measurement of ammonium and nitrate can be used to develop control schemes.
  - Energy reduction
  - Compliant effluent discharge levels