PROCESS TECHNOLOGY FOR PLANT OPTIMIZATION

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Great Lakes Region

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WWOA Lake Michigan District
Sturgeon Bay, WI
TREATMENT IS A HIGHLY VARIABLE OPERATION

Operator Questions -

• What to measure – and why?
• Where to measure it?
• Is a daily grab sample representative, good enough?
  – Hint: It is not
• Is my plant running as designed?
• Is my instrument giving me correct readings?
• What do I do with the data?
• Do the chemical, power savings matter?
  – Hint: Absolutely
TREATMENT IS A BUSINESS

• Retiring workforce - Institutional knowledge is leaving the industry

• Changing Raw Materials
  – Factories come and go
  – Population changes
  – I&I / Pb mitigation

• Budget concerns

• Compliance regulations

• Data management
  – Common Platform / Language
  – Data Security
  – Remote Access

Everyone is being asked to do more with less but how?
BLACKBOXING:
“The way scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become.”
INTERNAL COMPLEXITY, EXTERNAL SIMPLICITY
“BLACK BOXES” IN EVERYDAY LIFE

Real world systems:
- Incredibly complex input parameters
- No two days are the same (even minute by minute)
- Critical for Health, Safety, Performance
- Not conceivable to measure by a single person
- Variability in output is ALWAYS negative
WASTEWATER PROCESS CONTINUUM

Passive (watch)
- Do Nothing
- Grab Samples
- Online Analysis
- Data: Aggregate
- Analyze Report
- Decision Support: Detect
- Diagnose Predict
- Control/ Optimize Processes
- Control/ Optimize Facilities

Active (control)

SERVICE
- Lab Equipment / Chemistries
- Process Equipment
- WIMS
- Prognosys/ Sensor Verification
- RTC
- Claros

HACH
Be Right™
CLAROS PROCESS MANAGEMENT - REAL TIME CONTROL

What is RTC?

Real Time Control

But what does that really mean?

Advanced Process Optimization

Exactly what a good operator would do if they had unlimited time and no other responsibilities

Well what does that mean?
WHAT DO WE REALLY MEAN?

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.”

H. James Harrington
WHY DO WE DO IT?

Is it really all about the money?
WHY DO WE DO IT?

So it’s all about the environment then?
LET’S THINK ABOUT WHERE WE ARE

Compliance is King

This approach drives avoidance of penalties – “cost of doing business”, no public visibility of fines

Therefore, more is better... Isn’t it? At what cost?

More air
More chemical
More Capacity

= Robust Compliance

At the cost of energy / labor / chemical wasted
SINGLE TARGET, MANY GOALS

Compliance

Efficiency

Sustainability

Environment

Process stability

So compliance is the only driver?
ENERGY CONSUMPTION IN BIOLOGICAL WWTP’S

Why target aeration processes?

Offer a large potential for savings
TARGET COST REDUCTION VIA MODEL BASED DESIGN

Step 1: Identify Process

Step 2: Use Good Data

Step 3: Build Virtual Plant

Step 4: Actionable results

**Table 1: Activated Sludge Model Configuration**

<table>
<thead>
<tr>
<th>Tank</th>
<th>Anoxic</th>
<th>Aerobic</th>
<th>Aerobic</th>
<th>Aerobic</th>
<th>Aerobic</th>
<th>Aerobic</th>
<th>Aerobic</th>
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</thead>
<tbody>
<tr>
<td>Volume</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
<td>0.180 MG</td>
</tr>
<tr>
<td>% of Airflow</td>
<td>0</td>
<td>25</td>
<td>18.8</td>
<td>18.8</td>
<td>18.8</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td>Primary Effluent</td>
<td>1,200 gpm, TKN:25mg/l, TSS:88 mg/l, BOD:135 mg/l, Temp: 15C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLSS</td>
<td>2,850 mg/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAS</td>
<td>1610 gpm from Clarifier to Anoxic Tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAS</td>
<td>21 gpm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blower Airflow</td>
<td>1700 SCFM @ 7 psig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RTC-N/DN Simulation**

By allowing the complete aeration basin to go between aerobic and anoxic reduces the amount time aeration is on by 55%, and Total nitrogen in the effluent by 72% with minimal increase of ammonia leaving the aeration basins.

**Table 2: Results from the RTC-N/DN Simulation**

<table>
<thead>
<tr>
<th>Effluent</th>
<th>Ammonia</th>
<th>Total Nitrogen</th>
<th>Power</th>
<th>Aeration Cost @ 50.10 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.15</td>
<td>7.70</td>
<td>1173</td>
<td>$42,914</td>
</tr>
<tr>
<td>RTC-N/DN</td>
<td>1.23</td>
<td>2.23</td>
<td>552</td>
<td>$10,215</td>
</tr>
<tr>
<td>Reduction</td>
<td>72%</td>
<td>35%</td>
<td></td>
<td>$33,699</td>
</tr>
</tbody>
</table>
DO SETPOINT CONTROL SYSTEM

Standard Aeration Model

Operator Defined Target

The more we measure, the more we can control
Concept ensures fast reaction on load peaks and stable outlet concentrations

ALGORITHM BASED NITRIFICATION CONTROLLER

Dynamic Model (ASM 1 for Nitrification)

\[
\frac{dNH_4}{dt} = \frac{NH_4_{IN} - NH_4_{set} - \mu \times TSS \times DO \times NH_4}{HRT + \frac{DO}{K_{DO}} + \frac{NH_4}{K_{NH4} + NH_4}}
\]

\[O_{set} = f(NH_4_{set}, NH_4-N_{inflow}, NH_4-N_{outlet}, Q_{in}, TSS, T, \mu_{Max}, \ldots)\]
WHY TARGET AN ANALYTICAL INPUT WHEN YOU ARE BEING JUDGED ON A REQUIRED OUTPUT?

- Under fixed DO control
- Normal treatment zone
- Wasted Volume
- Wasted Energy

NH4 Flow COD TSS

Aeration Basin

Decreasing NH4 - N

Target effluent NH4-N e.g. 1 mg/l

Claros Process Management
Ammonia Target
DO modulation

NH4-N ~ 0 mg/l
Actual Plant Process Data

Aeration Tank 1: Manual DO Control
Aeration Tank 2: ABAC Control (23 MGD)

15% Savings
$58,728/yr
The CPM / RTC Umbrella Portfolio

- For Chemical Phosphorus Removal
- Optimizes chemical dosing
- Designed for continuous flow plants
- Ensures compliance
- May reduce chemical cost
WHY HACH’S RTC FOR PHOSPHORUS CONTROL?

• Treatment Process is Optimized
  – Phosphorus load (Flow x Conc.) vs. Chemical effectiveness
• ROI is proven, can prove out cost benefit analysis of Precipitants
• Cost savings can be redirected
• Compliance worries are gone
• Hach offers packaged integration!
RTC-P

PHOSPHAX sc + Filtrax

Components

sc1000
- Controls RTC parameters
- Signal validation
- All communication capabilities

RTC
- Calculates set-points in real time
- Interface for dosing pump
- Install in PLC cabinet

Plant Flow
- Needed to determine loading

Dosing Pump
- Control pump feed of precipitant based on PO₄ concentration
"If we were high one week, we overfed ferric to make sure the average for the month was below our 1.0 mg/L total phosphorus limit."

The average dose was 300 gpd at 12.5 gph.

Now during months of higher loading, the ferric feed rate may increase from 3 gph to 10 gph.

"Estimated annual savings of $50,000 to $70,000 have more than paid for the system."

Besides affordability, a major benefit was peace of mind. Previously, staff worried about whether the plant was over or at its limit for the month. "Now, the RTC controls the dose and I know we will be within our limit,“
Hach Family of Phosphax Analyzers

Phosphax sc HR (High Range)
- (1-50 mg/L PO4-P)
- Aeration basin applications
- Muni/Industrial WW Inlet

Phosphax sc MR (Medium Range)
- (0.05-15 mg/L PO4-P)
- Aeration basin applications
- Surface water monitoring
- Industrial effluent

Phosphax sc LR (Low Range)
- (0.015-2 mg/L PO4-P)
- Aeration basin applications
- Surface water monitoring
- Industrial effluent

NEW!
New Photometric Unit

- Lower concentrations of Ortho-P in a sample require a longer measurement path length.

Beer-Lambert Law

Lambert’s and Beer’s Laws are combined to describe the attenuation of light by a solution. It is easy to see how the two standard photometric quantities can be written in terms of this law:

\[ I = I_0 10^{-\varepsilon c x} \]

Transmittance

\[ T = \frac{I}{I_0} \quad T = 10^{-\varepsilon c x} \]

Absorbance

\[ A = -\log\left(\frac{I}{I_0}\right) = -\log T \]
\[ A = \varepsilon c x \]

Phosphax sc MR : b= 18mm
Phosphax sc LR : b= 36mm
**New Photometric Unit**

- Glass cuvette is expected to last the whole life time of the analyzer- More durable vs plastic cuvette in most analyzers.

- Glass cuvette is less prone to air bubbles compared to plastic cuvette in most analyzers.

- Double path length reduces effect of bubbles, if any.

![Diagram showing light pathways through cuvettes]

\[ I_0 \rightarrow I \rightarrow I_0 \rightarrow 2b \]
SAMPLE CONDITIONING

FILTRATION MODULES

- The Filtration Module prepares sample through two ultra-filtration membranes (0.15 μ)
- Modules are immersed in the process tank.
- Peristaltic pump pulls the sample through one filter at a time, allowing for optimal cleaning.
- Unit automatically cleans by forcing vigorous stream of air bubbles against sides of the filter modules.
Additional Features, integration and operation

Available in indoor and outdoor versions
- The housing is weatherproof so that the unit can be installed right at the basin, even in the toughest climates.

Claros Enabled
- You can leverage Hach Water Intelligence to collect, manage and analyze data.
- Full Featured “Plug and Play” Digital sc controller.

Zero requirement to cool reagents
- Longer shelf life of reagents.
- Ships with at least a 4-month supply of reagents.

Automatic calibration and cleaning
- Automatic cleaning at customized intervals and automatic zero-calibration at each measuring cycle.
- Low maintenance.
Product Applications

Municipal Effluent

Surface Water Monitoring

Industrial effluent
Beta Test Insights
Beta Test Locations

2 locations in Wisconsin

4 locations in Germany
Comparable Lab and Process Results in Very Low Ranges

Beta Test
Janesville Phosphax sc LR
Against Lab Data

Concentration (mg/L PO4-P)
Lab vs Process Comparison – an Overlap

*Lab tests were done using TNT 843 chemistry/LZP269 cuvette and a Hach DR3900/6000 photometer
High Stability/Less Noise of the Measured Values with the New Phosphax sc LR

Beta-test
Phosphax sc LR (0.015 – 2.0)
Phosphax sc MR (0.05 – 15.0)
LIMIT OF 1.0 MG/L  SET POINT OF 0.9 MG/L
NEVER DEVIATES OUTSIDE OF 0.85 – 0.95
PROCESS MANAGEMENT

Standardized RTC control modules

• Adapt plant operation to varying load situations and plant performance
  – Improved compliance (minimize risk)
  – Reduced OPEX / Short ROI (economically viable)
  – Improved process transparency

All analytical input signals **validated** by **Instrument Management / PROGNOSYS®**
  – High reliability, high uptime
**PROCESS MANAGEMENT EXPERIENCE**

**Large number of installations**
- **2150 sites** in EU, US, China operating an CPM
  - 70% of plants between 2-8 MGD
- **3750 control modules** in operation
- Growing number of industrial CPM

**Experienced Global CPM Team**
- Growing team of CMP consultants
  - 28 in EU, 5 in US
- Sales & Service NA: 250 associates
- Centralized (US and EU) CMP Service/Commissioning experts providing remote support & monitoring
# REAL TIME CONTROL MODULES

<table>
<thead>
<tr>
<th>Type</th>
<th>RTC</th>
<th>Application</th>
<th>Compliance</th>
<th>Direct Savings on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient Removal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>P</td>
<td>Chemical P-elimination</td>
<td>$P_{tot}$</td>
<td>- Precipitant</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Sludge treatment/disposal</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>Nitrification (plug flow)</td>
<td>$NH_4-N$</td>
<td>- Energy (aeration intensity)</td>
</tr>
<tr>
<td>DN</td>
<td>DN</td>
<td>Denitrification (IRC / Ext. C)</td>
<td>$N_{tot}$</td>
<td>- Energy (DO recovery, IRC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- External Carbon</td>
</tr>
<tr>
<td>SZ</td>
<td>SZ</td>
<td>Swing zone adjustment</td>
<td>$N_{tot}$</td>
<td>- Energy (aerated volume)</td>
</tr>
<tr>
<td>N/DN</td>
<td>N/DN</td>
<td>Intermittent denitrification</td>
<td>$N_{tot}$</td>
<td>- Energy (aeration time/volume, DO recovery)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$NH_4-N$</td>
<td></td>
</tr>
<tr>
<td>OXD</td>
<td>OXD</td>
<td>Simultaneous denitrification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>DO</td>
<td>Aeration</td>
<td>$NH_4-N$</td>
<td>- Energy (controlled DO)</td>
</tr>
<tr>
<td>SF</td>
<td>SF</td>
<td>Nitrification (step feed)</td>
<td>$NH_4-N$</td>
<td>- Energy (aeration intensity)</td>
</tr>
<tr>
<td>MOV</td>
<td>MOV</td>
<td>DO Control</td>
<td>NA</td>
<td>- Energy (aeration intensity)</td>
</tr>
<tr>
<td>Sludge Mgmt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRT</td>
<td>SRT</td>
<td>Sludge age</td>
<td>$NH_4-N$</td>
<td>- Energy (for BOD removal)</td>
</tr>
<tr>
<td>ST</td>
<td>ST</td>
<td>Sludge thickening</td>
<td></td>
<td>- Polymer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Increased gas yield</td>
</tr>
<tr>
<td>SD</td>
<td>SD</td>
<td>Sludge dewatering</td>
<td></td>
<td>- Polymer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Sludge disposal</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DOS</td>
<td>DOS</td>
<td>Nutrient dosing</td>
<td>$N_{tot}$, $P_{tot}$, $NH_4$</td>
<td>- Urea</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Phosphoric acid</td>
</tr>
<tr>
<td>DAF*¹</td>
<td>DAF*¹</td>
<td>Dissolved Air flotation</td>
<td>COD, TSS</td>
<td>- Coagulant, Polymer</td>
</tr>
</tbody>
</table>
AN OPTIMIZED PROCESS SHOULD NOT BE A DREAM, IT SHOULD BE A STANDARD OPERATING PROCEDURE

In the wastewater industry, your plant equipment will be at its most efficient on the day the person who built it gives you the keys.

The plant process will be made most efficient by understanding how it responds to what must be treated.
Plant Energy Efficiency and Performance over time

What actually happens due to lack of intervention, maintenance and manpower

What should happen due effective operator management and experience

Performance gap
Increased operating costs and carbon footprint

When was the last time you benchmarked performance?
Can this primary tank be optimized?

Not until the inlet screens are repaired or replaced.
Can this sludge thickener be optimized?

Not until the process piping can adequately handle process flow.
Can this digester’s gas production be optimized?

Loss of tank volume due to grit and or solids build up
Can this dosing system be optimized?

Safety  Security  System Reliability
Can this final tank be optimized?

Small problems can become big problems due to lack of Maintenance
FINAL THOUGHTS....

You can not manage what you do not measure

If you do measure make sure that you KEEP measuring

In other words, clean, maintain and service your instrumentation or your control system will fail

Maintain your assets – control systems only add value on well maintained and well operated plants

It’s not all about the money – Optimization helps to drive sustainability, environmental policy, labor efficiency, and compliance