Overview

- Discuss strategies for how to evaluate your water usage and water systems onsite
- Review benefits and ways to perform a water assessment
- Overview of most common water treatment systems, how treatment programs are established, and review common issues and best practices
  - Reverse Osmosis
  - Boiler Systems
  - Cooling Tower
  - Wastewater Treatment
Common Misconceptions

- Water is “cheap”
- “More is better”
- Don’t mess with a process that isn’t broken!
- We don’t have any supply issues
- It’s too dirty to reuse
- We have no other use for it
Water Sustainability Index 2050

Water Supply Sustainability Index (2050)
- Extreme (412)
- High (508)
- Moderate (1192)
- Low (929)
Understanding Your Water Systems

- How are you being charged for water use and sewer?
- Do you understand your pretreatment, post treatment, and chemical program costs?
- Post treatment and sludge disposal costs?
- **Have you developed a water balance for the site?**
- What water quality is required for different users?
- What are your discharge limitations?
- What’s your company’s ROI threshold for water reduction projects?
Performing a Water Assessment

- “You can’t manage what you don’t measure”
- Take the time to do a water balance
  - Identify and quantify processes / applications and associated usages
- Consider:
  - Different water usage based on different shifts, product runs, times of year, etc.
- End result = a process water mass balance
Performing a Water Assessment
Performing a Water Assessment

- Gathering flows – utilize:
  - Flow meters
  - Equipment specs
  - SOP’s
  - Educated estimates
  - Observation
  - Resourcefulness
Performing a Water Assessment

- Gathering costs – identify total water cost:
  - Purchase / sewer costs
  - Treatment costs
  - Equipment costs
  - Pumping costs
  - Disposal / land application costs

“True” cost of water onsite often SIGNIFICANTLY higher than just purchase / sewer costs
Performing a Water Assessment

- If you know your systems and have a strong justification, anything is possible!

U.S. Water Implements First U.S. Zero Liquid Discharge System in Dry Grind Ethanol Facility

In the spring of 2006, Pacific Ethanol, Incorporated started their dry grind ethanol plant in Madera, California. One of the most unique features of this start-up was that it was the first ethanol plant in the country to be designed and operated with no liquid discharge to the environment. The process that allows for this environmentally friendly system was developed by U.S. Water.
Performing a Water Assessment

- Use all the resources at your disposal
- Time investment is usually the main reason for sites not wanting to perform a water assessment
- Start high level and work down to unit ops level
- Assemble a good team!
  - Operations
  - Maintenance
  - Engineering
  - Purchasing
  - Water Treatment Vendor
  - P2 group
Optimizing Your Water Systems – Pretreatment

- Clarification
- Cold Lime Softening
- **Sodium Zeolite Softening**
- Multimedia Filtration
- **Reverse Osmosis**
- Demineralizers
- Decarbonators
- Ultrafiltration
Reverse Osmosis

- ROSA and SIPP software analysis used to determine what % recovery can be obtained for a given RO
- Proper design, installation, and operation are critical to ensure good system performance
  - Incoming water quality
  - Flow Requirements
  - Upstream pretreatment
  - Scale potential
  - Chlorine elimination
  - Membrane Selection
  - Staging
  - Flux Rate
  - CIP
  - Controls and Instrumentation
Reverse Osmosis

**RECOVERY**

- Recovery describes how much of the feedwater passes through the membrane to become “product” or “permeate”
- Expressed in terms of percent of feed water flow
- Typical recovery ranges from 50% to 75% – can go as high as 85%
- Higher recovery means less wasted water
- Driven by RO system design and membrane selection

\[
\text{% Recovery} = \frac{\text{Permeate Flow}}{\text{Feed Water Flow}} \times 100
\]
Reverse Osmosis

**WHY SYSTEM RECOVERY IS IMPORTANT...**

- **If Recovery Exceeds** Design Limitations
  - Increased Potential for Scaling – Exceeding the Solubility Limits of Salts
  - Risk of Accelerated Fouling – Hydraulics of System Outside Specified Limits

- **If Recovery is Below** Design
  - Wasting water, chemicals, and energy

- **Benefits of Optimizing Recovery**
  - Save water, save chemicals, save energy, save money...
Reverse Osmosis

Common Issue in Iowa

- RO membranes permeate more water at higher incoming water temperatures
  - Common to see 10-20F incoming water temperature variation throughout course of the year
  - Have seen up to 40F water temperature variations

- Summer months leads to higher permeate flow rates and higher recoveries
  - Reduce water, chemical, electrical usage but can lead to scale formation if too high

- Winter months leads to lower permeate flow rates and lower recoveries
  - Increased water, chemical, electrical usage
Reverse Osmosis

**Example**

- 100 GPM Permeate RO System
- 50% Runtime
- Operating 350 days / yr

75% Recovery
Inlet Flow = 133 gpm
Permeate Flow = 100 gpm
Reject Flow = 33 gpm

70% Recovery
Inlet Flow = 142 gpm
Permeate Flow = 100 gpm
Reject Flow = 42 gpm

2.3 Million gals water usage increase per year!
# Reverse Osmosis - Monitoring

## Reverse Osmosis Operator Logs

<table>
<thead>
<tr>
<th>Operator Initials:</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO Machine:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pressures (Manual Gauges)

- Pre-Filter Pressure (psig)
- Post-Filter Pressure (psig)
- Cartridge Filter Pressure Drop = A-B (psi)
- Pump Discharge Pressure (psig)
- Membrane Feed Pressure (psig)
- Reject Pressure (psig)

### Flows

- Permeate Flow (gpm)
- Reject Flow (gpm)
- Feed Flow = G + H (gpm)
- Recovery Rate % = G/(G+H)*100 (%)

#### Normalized Permeate Flow

### Analytical Data

- Inlet Temperature (°F)
- Inlet pH
- Feed Conductivity (μmhos)
- Permeate Conductivity (μmhos)
- Reject Conductivity (μmhos)
- % Rejection = (1 - O/N)*100 (%)
- Feed Free Chlorine (ppm as Cl₂)
- Feed Total Chlorine (ppm as Cl₂)
- Feed Bisulfite (as SO₃)
- Inlet Hardness (as CaCO₃)
- Antiscalant Concentration
- Cartridge Filters Changed (Y/N)
- CIP Conducted (Y/N)
Reverse Osmosis -Troubleshooting

CLEANING FREQUENCY – DON’T WAIT TOO LONG!

Cleaning after 10-15% decline maximizes RO performance.

Cleaning after > 15% decline reduces RO performance.

Cleaning after 10-15% decline maximizes RO performance.

Waiting too long to clean reduces RO performance.

Cleaning after > 15% decline reduces RO performance.
Reverse Osmosis - Troubleshooting

CAUSES OF MEMBRANE FOULING PROBLEMS

High First Stage DP

- Typically due to particulate fouling and high incoming SDI
- Could also be due to microbiological fouling
→ Clean first stage with high pH cleaner(s) and high shear velocities

High Final Stage DP

- Typically due to scaling resulting from concentration of salts from more concentrated water
→ Clean final stage with low pH cleaner(s)
Troubleshooting - Inspecting, locating and eliminating sources of troubles within the system on both an ongoing and as needed basis, such as:

- Piping system leaks, damage, etc.
- Pressure vessel leaks, structural damage, O-ring seal damage, end cap and associated seal problems, etc.
- Membranes (physical damage, visual evidence of fouling, brine seal condition, telescoping, interconnectors and associated O-ring seals, end cap adapters and associated O-ring seals, etc.)
- Instruments and control system operation
- Pressure, flow or salt passage problems
Other Options to Consider

- Higher efficiency membranes
- Replace orifice plate with reject throttling valve
- Install VFD
- Adding stages to existing RO
  - % Recovery increase
  - Capacity increase without investment in new RO
- Extra RO capacity, can it be used elsewhere?
- RO reject reuse – cooling tower?
- Softener Regeneration
  - Right salt concentration?
  - Excess water usage?
  - Can brine be recovered?
Optimizing Your Water Systems – Boilers

- Primary goal of water treatment is to protect boiler, steam, and condensate systems from scale and corrosion.
- Pretreatment performance, conductivity control, and water treatment program all have large impact on how well the boiler is maintained.
- Soot can be just as insulating as scale!

% Boiler Efficiency Loss Due to Scaling

% Efficiency Loss

Scale Thickness (inches)
Cycles of concentration refer to the number of times the dissolved contaminants in the boiler are concentrated compared to the makeup water.

Conductivity is often used as a simple method of determining cycles.

\[
\text{Cycles of Concentration} = \frac{\text{Feedwater Flow}}{\text{Blowdown Flow}}
\]

\[
\text{Cycles of Concentration} = \frac{\text{Boiler Conductivity}}{\text{Feedwater Conductivity}}
\]

Example: \[
\frac{1000 \text{ umhos/cm}}{20 \text{ umhos/cm}} = 50 \text{ cycles}
\]
Cycles of Concentration Example

- Steam boiler producing average 50,000 lbs / hr steam
- Operating 350 days / yr
- 70% Condensate Return

50 cycles
Makeup Water = 27 gpm
Feedwater = 102 gpm
Blowdown = 2.1 gpm

20 cycles
Makeup Water = 30 gpm
Feedwater = 105 gpm
Blowdown = 5.1 gpm

- 1.5 Million gals water usage increase per year
- 5,920 MMBTUs energy savings by increased condensate return
- Assume $3 / MMBTU and $8 / 1000 gal “true” water cost
- $17,750 annual energy savings via increased condensate return
- $12,000 annual water savings
Optimizing Your Water Systems – Boilers

Common issues causing low cycles
- Conductivity probe calibration
- Conductivity controller programming
- Blowdown valve leaks
- Level control issues
- Poor pretreatment performance
- Poor chemistry control
- Boiler carryover
- Tube leaks
Optimizing Your Water Systems – Boilers

Condensate Return Example
- Steam boiler producing average 50,000 lbs / hr steam
- Operating 350 days / yr
- 50 cycles

85% Condensate Return
Makeup Water = 17 gpm
Feedwater = 102 gpm
Blowdown = 2.1 gpm

70% Condensate Return
Makeup Water = 25 gpm
Feedwater = 102 gpm
Blowdown = 2.1 gpm

- 4.0 Million gals water usage increase per year
- 9,857 MMBTUs energy savings by increased condensate return
- Assume $3 / MMBTU and $8 / 1000 gal “true” water cost
- $29,750 annual energy savings via increased condensate return
- $32,000 annual water savings
Optimizing Your Water Systems – Boilers

- **Flash Tanks**
  - Assist with condensate recovery or blowdown heat recovery

- **Blowdown Heat Exchangers**
  - Use blowdown water to preheat feedwater before entering boiler system

- **Economizers**
  - Further preheat feedwater prior to entering boiler
Optimizing Your Water Systems – Cooling Towers

- Often single largest user of water onsite
- Primary goal of treatment is to protect system from scale, corrosion, and biological growth
- Biological growth can be just as insulating as scale!
Optimizing Your Water Systems – Cooling Towers

Cycles of Concentration Example
- Use cooling tower from prior water balance example
- 260 gpm evaporation rate operating 350 days / year

8 cycles
Makeup Water = 298 gpm
Evap Rate = 260 gpm
Blowdown = 37 gpm

6 cycles
Makeup Water = 312 gpm
Evap Rate = 260 gpm
Blowdown = 52 gpm

- 7.5 Million gals water usage increase per year!
Factors that Influence Tower Cycles

- Saturation indices are typically used to determine how many cycles a tower can achieve without scaling.
- Most commonly used are LSI and RSI.
- Inputs are:
  - pH
  - Calcium Hardness
  - Alkalinity
  - Chlorides
  - Sulfate
  - TDS
  - Surface Temperatures

<table>
<thead>
<tr>
<th>LSI</th>
<th>RI</th>
<th>Conditions</th>
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<tbody>
<tr>
<td>3.0</td>
<td>3.0</td>
<td>Very strong tendency to form CaCO₃ scale.</td>
</tr>
<tr>
<td>2.0</td>
<td>4.0</td>
<td>Strong tendency to form CaCO₃ scale.</td>
</tr>
<tr>
<td>1.0</td>
<td>5.0</td>
<td>Moderate tendency to form CaCO₃ scale.</td>
</tr>
<tr>
<td>0.5</td>
<td>5.5</td>
<td>Slight tendency to form CaCO₃ scale.</td>
</tr>
<tr>
<td>0.2</td>
<td>5.8</td>
<td>Very slight tendency to form CaCO₃ scale.</td>
</tr>
<tr>
<td>0.0</td>
<td>6.0</td>
<td>Stable water</td>
</tr>
<tr>
<td>-0.2</td>
<td>6.5</td>
<td>Very slight tendency to dissolve CaCO₃ scale.</td>
</tr>
<tr>
<td>-0.5</td>
<td>7.0</td>
<td>Slight tendency to dissolve CaCO₃ scale.</td>
</tr>
<tr>
<td>-1.0</td>
<td>8.0</td>
<td>Moderate tendency to dissolve CaCO₃ scale.</td>
</tr>
<tr>
<td>-2.0</td>
<td>9.0</td>
<td>Strong tendency to dissolve CaCO₃ scale.</td>
</tr>
<tr>
<td>-3.0</td>
<td>10.0</td>
<td>Very strong tendency to dissolve CaCO₃ scale.</td>
</tr>
</tbody>
</table>
Optimizing Your Water Systems – Cooling Towers

How can we increase cycles?

- Conductivity & Level control
- Acid feed
  - Lowers alkalinity and pH in tower
- Softened water
  - Removes calcium hardness from makeup
- RO permeate feed
  - Lowers TDS, Sulfate, Chloride, Hardness, and Alkalinity in makeup
  - If excess RO capacity is available can be an excellent supplement to regular makeup
- RO reject feed
  - Situationaly acceptable if softener is upstream of RO
Optimizing Your Water Systems – Wastewater

- Very specific to each individual facility
- Many factors will influence how your treatment system performs but most critical factor is a good understanding of YOUR systems
  - What is being removed from your water
  - Design vs. current state
  - Water discharge limitations
  - Solids disposal methods
Optimizing Your Water Systems – Wastewater

Develop an Action Plan

- Clearly state your goals
  - Get in compliance
  - Reduce surcharges
  - Increase capacity
  - Reduce sludge discharge
  - Reduce treatment costs

- Survey your facility!
  - Develop process map of both wastewater facility and what’s feeding to it
  - Pay attention to both average and peaks

- Review your options
  - Equipment / Control Upgrades
  - Chemical modifications
  - Operation Changes
  - Communication

- Capacity Issues?
  - Try source point reduction!
Common Factors Influencing Wastewater Treatment

- Equalization / Holding Time
- Flow Rates
- pH
- CIPs & Sanitization
- Air Flow and Distribution
- Sludge % Solids
- Chemical Selection
- Chemical Feed Dosing & Location
- Discharge Limitations & Onsite Testing
- Jar Testing & Adjustments
Summary

- Establishing current state via water assessment is important first step towards identifying improvement opportunities

- Use water assessment to establish highest value opportunities & evaluate all your options to improve
  - Equipment, Chemical, Operational, etc.

- Taking the time to monitor and understand your systems is critical to ensuring they’re operating at peak efficiency!
Questions?

Thank you for your time!

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