How to Select Industrial Water Reuse and Energy Management Solutions

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PRESENTED BY:
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BCEE
Principal
• What are the Drivers for Reuse?
• Water Footprint and Water Ratios
• Integrated Approach and Water Balance Tools
• Reuse Considerations and Quality Issues
• Treatment Alternatives
• System Design Issues
• Examples (Pharmaceutical & Beverage)
• Summary
What are the Drivers?

- Corporations have Sustainability Goals for Water, Energy and Greenhouse Gases
- ISO 26000 – Guidance on Social Responsibility – Public Image
- Business/Production Risks – Disruption from Droughts and Water Quality Concerns
- Water and Energy Cost Reduction
- Production Increase/New Products
Water Footprint for a Product

- The volume of fresh water used to produce the product summed over the various steps in the production chain
  - Green water footprint – rainwater
  - Blue water footprint – surface and groundwater
  - Grey water footprint - wastewater

Reference: Water Footprint Network
## Water Footprint Examples

<table>
<thead>
<tr>
<th>Product</th>
<th>Water Used</th>
<th>Water Used gal/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple (One)</td>
<td>18 gal.</td>
<td>--</td>
</tr>
<tr>
<td>16 oz. Tea</td>
<td>18.5 gal.</td>
<td>148</td>
</tr>
<tr>
<td>Pint of Beer (16 oz.)</td>
<td>40 gal.</td>
<td>320</td>
</tr>
<tr>
<td>16 oz. Diet Cola</td>
<td>33 gal.</td>
<td>264</td>
</tr>
<tr>
<td>16 oz. Coffee</td>
<td>37 gal.</td>
<td>296</td>
</tr>
<tr>
<td>16 oz. Milk</td>
<td>106 gal.</td>
<td>848</td>
</tr>
<tr>
<td>16 oz. Wine</td>
<td>63 gal.</td>
<td>504</td>
</tr>
<tr>
<td>1 lb. Chicken</td>
<td>467 gal.</td>
<td>--</td>
</tr>
<tr>
<td>1 lb. Beef</td>
<td>1,857 gal</td>
<td>--</td>
</tr>
</tbody>
</table>

Reference: Water Footprint Network (Research by Cranfeld University in UK (2011))
Water Use Ratio (in a Facility)

\[ WUR = \frac{Total \ Water \ Used}{Total \ Beverage \ Production} \]

WUR has become common expression for water efficiency

Origin:
- Adopted by United Nations Global Compact
- Global Reporting Initiative voluntary, internationally recognized framework for sustainability reporting that provides the opportunity to measure and report our performance in key sustainability areas
- 2006 – Current guidelines launched
<table>
<thead>
<tr>
<th>Product</th>
<th># of Facilities Surveyed</th>
<th>Water Use Ratio L/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2009</td>
</tr>
<tr>
<td>Carbonated Soft Drinks</td>
<td>725</td>
<td>2.23</td>
</tr>
<tr>
<td>Bottled Water</td>
<td>131</td>
<td>1.55</td>
</tr>
<tr>
<td>Brewing</td>
<td>296</td>
<td>4.53</td>
</tr>
<tr>
<td>Distillery</td>
<td>80</td>
<td>38.35</td>
</tr>
<tr>
<td>Winery</td>
<td>27</td>
<td>3.78</td>
</tr>
</tbody>
</table>

Water Use Breakdown

83 billion gallons water used at 900 bottling plants worldwide – equivalent to double the City of Chicago

Water use ratio at plants average about 2.4 gallons used per gallon of product

Water footprint is 70 gallons per gallon of product with most of this water needed to grow the sugar

Goal is 20 % reduction in water ratio from 2004 to 2012 – they are on target now

What is next generation of technologies ?

Source:  Paul Bowen of Coca-Cola – NJWEA Industrial Seminar (2011)
Comparison Pharmaceutical & Food & Beverage

Similarities

• Drivers
• Regulatory (e.g., EPA, FDA)
• Contact or use of treated water with product is not acceptable
• Water users in facility (e.g., utilities)

Differences

• Active Pharmaceutical Ingredients (APIs) Concerns
• More solvents used in pharmaceutical industry
• High strength wastewaters for energy recovery in food and beverage – more use of anaerobic digestion
Use An Integrated Approach to Water Treatment & Reuse
Use Collaborative Team Approach

- Mobilize a Team – include those closest to the problems
- Include production, water utilities, wastewater operators, EHS compliance etc.
- Outside consultant to facilitate and bring broad background at other facilities
- Management and team commitment
- Frequent communications and training
Develop “Representative” Water Balance Diagram
Reuse System Considerations

System Design Considerations

- *System Reliability
- *Reuse Water Volume
- *Total Life Cycle Cost
- *Regulatory Compliance
- Food Safety
  - Pathogen control
  - *Microbiological control
- Food Quality
  - Suspended solids
  - Dissolved solids
  - Cycling

Capital Investment
Ongoing Operating Expenses

Reference: U.S. Water Services – Gary Engstrom (September 2013)
Key Target Water Users at Plants

- Pharmaceutical & Food & Beverage
- Cooling Towers
- Scrubbers for Air Pollution Control
- Chillers, Boilers and HVAC (Air Handling Condensates)
- Lawn Sprinklers/Irrigation
- Cleaning Water for Clean-in-Place Systems, etc. (e.g., tanks, bottle washing)
- Cafeteria
- Washrooms and showers
- Other Water Users – Laboratories etc.
- Food
- Fluming or transport (e.g., tomatoes & beans)
- Pork (e.g., spraying & cooling of livestock, scalding tubs & washing of animals)
Reuse Water Considerations

- Fouling – Heat Transfer Loss, Plugging
  - Iron (Fe)
  - Silica
  - Organics
  - Dirt, Dust, TSS
  - Extracellular Polysaccharides (EPS)

- Microbiological – Fouling
  - Potential Pathogens (LP)
  - Nutrients – NH₃, P
  - TOC/BOD – Food
Reuse Water Considerations

• **Scale – Heat Transfer Loss, Plugging**
  • Calcium (Ca)
  • Magnesium (Mg)
  • Barium (Ba)
  • Strontium (Sr)
  • Carbonate ($\text{CO}_3^{2-}$)
  • Phosphate ($\text{PO}_4^{3-}$)
  • Sulfate ($\text{SO}_4^{2-}$)
  • Silicate ($\text{SiO}_2^{2-}$)

• **Corrosion – Equipment Life (Metallurgy)**
  • Total Hardness (Ca, Mg)
  • Manganese (Mn) – Mild & Stainless Steel
  • M-Alkalinity
  • Fouling
  • pH
  • Chloride ($\text{Cl}^-$) – Stainless Steel
  • Ammonia ($\text{NH}_3$) – Copper (Cu), Admiralty Brass
Treatment Alternatives

- Flow Equalization
- pH Control
- Screening
- Oil and Grease (D.A.F.)
- Primary Clarification
- Anaerobic Treatment
- Activated Sludge and MBRs
- UF and RO
- UV Disinfection
Non-Potable Reuse: Industrial Reuse
Pharmaceutical Plant Rainwater Harvesting

60% Reduction in City Water Use
Business Risk Driver on Water Supply Available

- 52,000 gpd to Cooling Tower 1
  - 9,000 gpd
- 33,000 gpd to Cooling Tower 2
  - 6,000 gpd
  - 19,000 gpd to R.O.
    - 6,000 gpd to Wastewater Treatment
- 29,000 gpd to Cooling Tower 3
  - 4,000 gpd
- 33,000 gpd from City Water
- 8,000 gpd from AHU Condensate
- 50,000 gpd from Rainwater / Groundwater
- 10,000 gpd from R.O. Reject USP

Total Makeup Water: 114,000 gpd

Total Rainwater/Groundwater: 50,000 gpd

Total Wastewater Treatment: 13,000 gpd
Beverage Plant Water Reuse Zero Liquid Discharge (ZLD)
Pharmaceutical – Recommended System – Membrane Filtration (MF or UF) + RO
### Pharmaceutical Plant Recycle/Reuse Treatment System-Required Effluent Concentrations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Evapco/Carrier Water Quality Guidelines</th>
<th>Required Makeup Water Quality (at CoC=3) with safety factor = 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>su</td>
<td>7 - 9</td>
<td>7 - 9</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>&lt; 25</td>
<td>6.7</td>
</tr>
<tr>
<td>Conductivity</td>
<td>umhos/cm</td>
<td>&lt; 4,000</td>
<td>1067</td>
</tr>
<tr>
<td>Alkalinity as</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaCO₃</td>
<td>mg/L</td>
<td>&lt; 350</td>
<td>93</td>
</tr>
<tr>
<td>Chlorides</td>
<td>mg/L</td>
<td>&lt; 500</td>
<td>133</td>
</tr>
<tr>
<td>Silica</td>
<td>mg/L</td>
<td>&lt; 150</td>
<td>40</td>
</tr>
<tr>
<td>Total Bacteria</td>
<td>cfu/ml</td>
<td>&lt; 10,000</td>
<td>2667</td>
</tr>
<tr>
<td>Iron Oxides</td>
<td>mg/L</td>
<td>&lt; 1.0</td>
<td>0.27</td>
</tr>
<tr>
<td>Ammonia</td>
<td>mg/L</td>
<td>&lt; 0.5</td>
<td>0.13</td>
</tr>
</tbody>
</table>
## Pharmaceutical – Comparison of Costs
(20,000 gpd system)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Total Capital ($ Millions)</th>
<th>Total Annual O&amp;M ($ Millions)</th>
<th>Total Present Worth $ Millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UF/MF + RO (Two-Pass)</td>
<td>1.33</td>
<td>0.23</td>
<td>2.95</td>
</tr>
<tr>
<td>2</td>
<td>Disk + Cartridge Filters + RO</td>
<td>0.95</td>
<td>0.12</td>
<td>1.82</td>
</tr>
<tr>
<td>3</td>
<td>Filtration/Softening</td>
<td>0.39</td>
<td>0.23</td>
<td>2.01</td>
</tr>
</tbody>
</table>

1 Based on 7%, 10 years
Distillery - Non-Process Control Strategies
Distillery - Non-Process Control Strategies

Chemical Pretreatment

Wastewater Influent

Reactor Tank

Precipitating Agents

Concentration Tank

Recirculation Loop

Filtration

Membrane Modules

Cleaning Loop

Neutralization

Wastewater Feed Equalization

Settling

Dewatering Equipment

To (A)

Filter Press

Solids to Disposal

MF Permeate to Reverse Osmosis System
NPWW Reuse Treatment System

Alternative 1b - EQ + Chemical Pretreatment + MF + RO + UV (Divert MF Permeate to Seal Water System, RO only for CT Make-Up Water)

<table>
<thead>
<tr>
<th>Reuse System Influent</th>
<th>MF PERMEATE</th>
<th>RO PERMEATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>86,000 gpd</td>
<td>85,570 gpd</td>
<td>15,428 gpd</td>
</tr>
<tr>
<td>50 mg/L TSS</td>
<td>1 mg/L TSS</td>
<td>0.15 mg/L TSS</td>
</tr>
<tr>
<td>1,517 mmhos</td>
<td>1,442 mmhos</td>
<td>360.4 mmhos</td>
</tr>
<tr>
<td>0.5 mg/L Phosphate</td>
<td>0.48 mg/L Phosphate</td>
<td>0.12 mg/L Phosphate</td>
</tr>
<tr>
<td>0.5 mg/L Ammonia</td>
<td>0.60 mg/L Ammonia</td>
<td>0.15 mg/L Ammonia</td>
</tr>
<tr>
<td>76 mg/L silica, as SiO2</td>
<td>1.14 mg/L silica, as SiO2</td>
<td>0.28 mg/L silica, as SiO2</td>
</tr>
<tr>
<td>32 mg/L Chloride</td>
<td>31.5 mg/L Chloride</td>
<td>0.79 mg/L Chloride</td>
</tr>
<tr>
<td>1.7 Iron, as Fe</td>
<td>0.02 mg/L Iron, as Fe</td>
<td>0.00425 mg/L Iron, as Fe</td>
</tr>
<tr>
<td>8 SU (pH)</td>
<td>8 SU (pH)</td>
<td>8 SU (pH)</td>
</tr>
</tbody>
</table>

Chemical Reaction System

Chemicals (Rxn System):
- FeO3
- NaOCl
- MgCl2
- Soda Ash

Microfilter (MF)

Reverse Osmosis (RO)

Seal Water Reuse Tank

Sludge Press

Dry Cake

* COD/BOD Removed Prior to UF/RO (< 5 ppm)
* O&G Removed Prior to UF (< 2 ppm), prior to RO (<0.2 ppm)
* Silica Softening Prior to UF/RO (< 1 ppm)
* Chlorine for Iron Oxidation prior to RO (Iron < 0.4 ppm)

** Estimated removals - pilot testing required to confirm removals

FILTRATE RETURN TO EQ

UV

OFF-SITE

Roll-off
Pork Manufacturing Plant Water Reuse

- 3.5 MGD water usage – 33% reused for non-potable uses including: livestock spraying/cooling, inedible rendering, utilities, carcass washing, scald tubs and cooling water

- Approval for water reuse – USDA, EPA and FDA

- Reconditioned process water criteria was established: pH, turbidity, fecal coliform, total coliform, total plate count, chlorine residual and TOC

- Process wastewater plant – activated sludge

- Advanced or reconditioned water plant – conventional water treatment processes including UV disinfection
• Use the Integrated and Collaborative Team Approach
• Serious droughts in CA, AZ, Texas and Georgia and are not going away
• Corporations benefit from social, economic and environmental (triple bottom line) evaluations
• Industries have different issues but similar water reuse approaches and technologies
• Technologies are proven and available – the Time is Now!
Questions?