Overview

Reverse Osmosis Life Cycle Costs

Macro trends/drivers
- Increasing population growth & consumption
- Reduced water quality & quantity
- Increasing public awareness & understanding
- Increasing use of chloramines by municipalities
- Emergence of high efficiency water consuming appliances

Implications
- Water will become more expensive over time
- Water quality will deteriorate as supplies dwindle
- Alternative treatment methods needed... Like RO
Impact of Water

Important to our customers & guests

Guest Satisfaction
- Improves beverage & ice quality
- Reduces off-taste & odor
- Reduces spotting & filming on glassware

Operational Efficiency
- Increased throughput
- Reduced energy usage
- Improved reliability
- Reduced maintenance
- Reduced downtime

Modern Kitchen Equipment

Warranties contingent on meeting “water spec”

Typical water constituents
- Dissolved solids (TDS)
- Hardness (Ca/Mg)
- Alkalinity
- Choline/chloramine
- Chlorides
- Silica
- Others

Treatment options
- RO often only way to meet equipment water spec

Peter Voss
Sr. R&D Program Leader, Ecolab Water Solutions

Experience
- Ecolab: 2004-Present
- University of Minnesota: B.S. Chemistry
- Indiana University Kelley School of Business: MBA

Career Highlights
- 9 years in the water purification industry
- 15 years of polymer chemistry experience
- Holder of 9 US patents
Water Basics

Reverse Osmosis Life-Cycle Costs

Water Impurities
Water contains "stuff" that must be removed

- Suspended Solids
  - Bacteria
  - Virus
- Dissolved Solids
  - Organic
  - Inorganic

Impurities

- Removed by Mechanical Filtration
- Removed by Carbon Filtration
- Removed by Ion Exchange or RO

Particulate Removal
Mechanics of removing particles from water

Filtration Methods
- Mechanical (dead-end)
- Particle larger than space between filter fibers
- Particle trapped in fibers
- Cross-flow
- Reverse Osmosis (98% rejection)
- Nano-filtration (50-90% Rejection)

Effectiveness
- Standard carbon filtration: 5.0 µm
- Advanced carbon filtration: 1 µm
- Reverse Osmosis: 0.0005 µm
- Fun fact: Human hair = 100 µm
Filtration Spectrum
Comparison of various water filtration solutions

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Filtration</th>
<th>Softening</th>
<th>RO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Chlorine</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Hardness</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>TDS</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

RO can be thought of as a very “tight” filter that fills the gap left by standard carbon filtration and water softening.

Treatment Options
Common platforms used in foodservice arena

Customer water quality
- Ecolab R&D water database
- 15-20% samples > 500 ppm TDS
- 80% samples > 7 grains hardness
- All candidates for RO
- RO often best (or only) solution

Customers with water quality specs
- Beverage companies
- Coffee companies
- Food service operators
Reverse Osmosis Life-Cycle Costs

RO Applications

Brewed beverages
• Coffee, Tea, Espresso
• Improves product quality, clarity, & taste

Steamers & Combi-ovens
• High-temperature cooking applications
• Prevent scale & corrosion on heat transfer surfaces

Ice Machines
• Produce top-quality crystal clear ice
• Prevent scaling & decrease maintenance costs

Benefits
• Prevents scale buildup on heat transfer surfaces
• Ensures compliance with OEM warranty specs
• Reduces downtime & maintenance costs
• Extends equipment life

Guidelines for use
• TDS > 60 ppm
• Hardness > 5 grains
• Silica > 13 ppm
• Alkalinity > 20 ppm
• Chlorides > 30 ppm
• pH < 7.5
**RO Applications**

**Ice machines**

**Benefits**
- Crystal clear, pure, long lasting ice
- Reduced maintenance costs
- Improved beverage quality/clarity

**Guidelines for use**
- TDS > 300-400 ppm
- Hardness > 10-12 grains
- Issues with ice cube cloudiness

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**RO Applications**

**Brewed beverages (coffee | tea | espresso)**

**Benefits**
- Improved beverage clarity
- Longer holding time
- Less scale buildup
- Reduced maintenance costs
- Extended equipment life

**Guidelines for use**
- TDS > 150-200 ppm
- Hardness > 5 grains

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**Brewed Beverages**

*Vastly improved clarity & overall quality*

**Untreated**
- 100 NTU

**Treated**
- 10 NTU
Reverse Osmosis Life Cycle Costs

RO 101

Basic Terminology
Commonly used concepts & terms

Permeate (product water)
• De-mineralized water that has passed through a membrane
• AKA: Product water

Concentrate (reject water)
• Water containing minerals/impurities filtered by membrane

Recovery
• % of feed water that becomes permeate (good water)

Rejection
• % of feed water that becomes concentrate (bad water)

Flux
• Permeate production of a membrane (GPD)

RO Membranes
Principle of operation

Reverse osmosis systems are designed to remove (reject) dissolved mineral salts, organic molecules and other impurities from water by forcing water to pass through a semi-permeable membrane...

Feed Water

Water Out (Permeate)
Salts free water exiting the system is called permeate, and can range from 40-80% of influent water flow

Membrane

Waste (Reject)
Water laden with solids exits the system as waste water, called concentrate
Typical RO System
Basic components

Factors Affecting Life-Cycle Costs

RO Life-Cycle Costs
Controllable & uncontrollable factors

Controlable
• Pre-treatment
• System recovery & reject rates
• System configuration (single vs. multi POU)
• Line pressure vs. membrane pump
• Storage tank configuration
• Other uses for reject water
• Preventative maintenance/service

Uncontrollable
• Incoming water quality
• Incoming water temperature
• Treated water peak demand & daily usage/demand
• Desired/required effluent water quality (TDS)
• Reactive service
Influent Water Quality Impurities affecting RO performance/costs

<table>
<thead>
<tr>
<th>Impurity</th>
<th>What is it?</th>
<th>Impact on Membranes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment</td>
<td>Silt, dirt, debris, etc.</td>
<td>Fouls membranes &amp; impedes water flow</td>
</tr>
<tr>
<td>Chlorine &amp; Chloramines</td>
<td>Sanitizer fed by municipalities to kill micro-organisms</td>
<td>Degradates materials &amp; adhesives used in membranes</td>
</tr>
<tr>
<td>Hardness</td>
<td>Calcium (Ca)</td>
<td>Combines w/alkalinity &amp; forms scale on membranes</td>
</tr>
<tr>
<td></td>
<td>Magnesium (Mg)</td>
<td></td>
</tr>
<tr>
<td>Organics</td>
<td>Decaying plant, animal, human matter</td>
<td>Fouls membranes &amp; impedes water flow</td>
</tr>
<tr>
<td>Iron &amp; Manganese</td>
<td>Mineral contaminants that are not common but can occur</td>
<td>Requires special pretreatment to prevent membrane fouling</td>
</tr>
</tbody>
</table>

Influent Water Quality Impact on RO life-cycle costs

You get what you get...
- Water quality dependent on source
- Surface water: Higher in suspended solids/organics
- Ground water: Higher in dissolved solids
- Either way: Must “deal” with it

Direct relationship between water quality & costs
- Water quality dictates level of pretreatment required
- Better water quality → less pre-treatment → lower TCO
- Worse water quality → more pre-treatment → higher TCO

Pretreatment Balancing act... Pretreatment is not “free”

Pretreatment is non-optional
- Required to protect critical membranes

Common forms of pre-treatment
- Mechanical filtration: Removes sediment, dirt, silt
- Carbon filtration: Removes chlorine/chloramines
- Ion exchange (softening): Removes hardness
- Anti-scalants: Chemically conditions hardness

Impact of good pretreatment on life cycle costs
- Achieve longer membrane life → lower costs
- Operate RO at higher recovery → lower costs
System Recovery
Percent of incoming water permeate

\[ \% \text{ Recovery} = \frac{\text{Permeate}}{\text{Permeate + Concentrate}} \]

<table>
<thead>
<tr>
<th>System</th>
<th>Feedwater (gpm)</th>
<th>Permeate (gpm)</th>
<th>Concentrate (gpm)</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
<td>50%</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>1.5</td>
<td>0.5</td>
<td>75%</td>
</tr>
</tbody>
</table>

System Recovery
Balancing the costs

High Recovery (60-80% permeate)
- Less water to drain ⇒ lower water operating costs
- High Recovery ⇒ membranes more prone to plugging & fouling
- Shortened membrane life ⇒ higher membrane costs

Low recovery (30-50% permeate)
- More water to drain ⇒ higher water operating costs
- Low Recovery ⇒ membranes less prone to plugging & fouling
- Extended membrane life ⇒ lower membrane costs

System Rejection
Focus on water quality requirements

High Rejection (98%+) Membranes
- Higher costs
- Very high quality permeate
- Less tolerant to poor pretreatment
- More prone to membrane fouling

Lower Rejection (90-95%) Membranes
- Lower costs
- Slightly reduced permeate quality
- Meets requirements of most food service applications
- More tolerant to poor pretreatment
- Less prone to fouling
Desired Effluent Quality
Not all applications are created equal

Brewed Beverages          Steamers/Combi-Ovens

Specialty Coffee Association (SCAA) Water Quality Standard

Treated Water Demand
Trade-off between system size & storage capacity

Water storage tanks are required to meet the “on-demand” water flow requirements of most food service equipment

- **Atmospheric tank**
  - Smaller foot print – higher pressures with delivery pump
  - Larger foot print – lower delivery pressures

Storage tank size relative to water needs/demand
- Smaller tank ÷ Larger (costlier) RO but smaller footprint
- Larger tank ÷ Smaller (cheaper) RO but larger footprint

Water Temperature
Key factor in performance of RO membranes

Inverse relationship between temperature & output
- As water temperature drops – membrane output drops
- At 50°F, membrane output is 50% less than at 77°F

Must upsize for cold water
- Colder climates require RO systems with increased output and/or increased permeate storage capacity
- Systems should be sized for the coldest time of the year to consistently meet demand
- Larger system size ÷ higher cost
System Configuration
Single versus multi point-of-use systems

Single Point-of-Use
• Focus on water requirements of 1 appliance (i.e. steamer)
• Simplified sizing & less complexity
• Several systems may be required for complete coverage

Multi Point-of-Use
• Treat several water consuming appliances with a central system
• Water treatment cost spread over multiple pieces of equipment
• Fully leverage the benefits of demineralized water
• Requires greater understanding of water usage needs & patterns to properly size system

Alternate Uses For Reject
Collecting & reusing reject water can reduce TCO

Reject water is potable
• Not “bad” water
• Higher concentration of minerals vs. untreated water

Requires collection of reject water & (re)distribution
• Additional space required
• Trade-off between on-going expense (reject water) vs. upfront system cost

Service
Proper preventative service reduces TCO

Preventative service (scheduled)
• Pretreatment – proactive 6 month prefiter change-out
• Proactive 1-2 year membrane change-out
• Routine monitoring of system insures proper system performance

Reactive service (wait until broken)
• Membrane failure – potential equipment damage
• Unexpected equipment downtime – lost revenue
• Uncertain system performance
• Expensive service
Financing
Purchase upfront verses lease
Purchase (buy)
• Higher upfront capital costs
• Requires maintenance program or service agreement
• Potential variable monthly maintenance/repair expenses
Lease/Rent
• Lower upfront capital costs
• Preventative & reactive service typically included
• Fixed monthly expense with little/no variability

Reverse Osmosis Life Cycle Costs
Summary
(Rules of Thumb)

Rules of Thumb
• Smaller systems (<250gal/day), lower recovery = lower TCO
  • Water costs are relatively low vs. potential membrane / system failure costs
  • 50% recovery = $30/month in added water costs vs. 75% recovery ($6/1k gallon)
• Higher recovery (>60%), better pretreatment = lower TCO
  • Antiscalant prefilter is small upgrade cost vs. membrane / system failure costs
  • Scale inhibiting prefilter = additional (1x@3 months)
• Higher Rejection,95%+(steamers), better pretreatment = lower TCO
• Line pressure RO membrane vs. high pressure membrane ⇒ lower TCO
  • Economical high output low-energy membranes are readily available
  • With adequate line pressure (35psi), membrane pump systems are not required
• Smaller water storage tank relative to water demands ⇒ higher TCO
  • Requires larger higher output RO with bigger membranes