leading the way in MBR

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global water challenges

- availability
- quality
- demand
- infrastructure
- environment

path to reduce water footprint is reuse
The Future of Wastewater Treatment ….

Is Resource Recovery

**Today… wastewater as a burden to treat & discharge**

- Biosolids to landfill
- Micropolllutants to environment
- Waste water discharge to sensitive areas
- Green House gas emissions
- Huge energy drain

Wastewater  ➔  Energy

**Future… ‘opportunity water’ treated to recover valuable resources**

- Water for irrigation and reuse, limited solids disposal
- Energy back to grid
- Recovery of nutrients (N, P)
- Elimination of public health concerns

Organic waste  ➔

**Shift from wastewater treatment to resource recovery**
Advantages of MBR Technology vs. CAS

Achieves secondary and tertiary treatment in one compact step

- Footprint
- Cost
- Reliability
- Effluent Quality
membrane bioreactor technology
MBR acceptance and adoption

*Global* MBRs being installed in all corners of the globe.

**growth**

Installed capacity growing exponentially

** global **

MBRs being installed in all corners of the globe.
Simplifying Wastewater Treatment

- Replaces conventional clarification, aeration and filtration
- Combines the physical barrier characteristics of a membrane with biological treatment
- Produces high quality effluent at all times
ZeeWeed* MBR

- **Bioreactor**: 8,000 to 10,000 mg/l
- **Membrane** (liquid/solids separation)

**Influent**

**Filtrate (Effluent)**

- Hi-Rate Biological Treatment in compact footprint
- Absolute / Positive Filter with consistently high effluent quality

Simpler more reliable process

*Trademark of SUEZ; may be registered in one or more countries
Driving the Growth

**MBR makes sense for all plant sizes**

**competitive LCC**
- MBR competitive with CAS - cheaper for nutrient removal and reuse
- membrane costs, advancement in design and reduction in energy

**small footprint**
- WWTP often encroached on by expanding cities
- significant expansion in existing footprint and assets

**technology maturation**
- proven performance
- membrane life exceeds estimates
- simple and reliable operation

**demand for high quality effluent & reuse**
- regulations pushing for higher quality effluents
- stress on freshwater resources driving reuse
Comparing MBR to Conventional Treatment

Changes to MBR CAPEX…
• Product Costs
• Technology Innovation
• Wrap Around Costs

Changes to MBR OPEX…
• Technology Innovation
• Optimized Design and Operation

MBR Offers ….
• Lower Lifecycle cost for enhanced nutrient removal and water reuse
• Requires less land, concrete, and equipment installation costs
## Requirements for Reuse Water

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional effluents</th>
<th>Water reuse standard</th>
<th>MBR Achieves</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>25 - 50 mg/L</td>
<td>&lt; 2 mg/L</td>
<td>✓</td>
</tr>
<tr>
<td>Turbidity</td>
<td>10 - 30 NTU</td>
<td>&lt; 0.2 NTU</td>
<td>✓</td>
</tr>
<tr>
<td>BOD</td>
<td>25 - 50 mg/L</td>
<td>&lt; 2 mg/L</td>
<td>✓</td>
</tr>
<tr>
<td>TDS</td>
<td>N/A</td>
<td>&lt; 500 mg/L</td>
<td>N/A</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>10 - 30 mg/L</td>
<td>&lt; 10 mg/L</td>
<td>✓</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1 - 30 mg/L</td>
<td>0.1 - 2 mg/L</td>
<td>✓</td>
</tr>
<tr>
<td>Coliforms</td>
<td>$10^5 - 10^7$ cfu/100 mL</td>
<td>&lt; 2.2 #/100 mL</td>
<td>✓</td>
</tr>
<tr>
<td>Virus / Protozoa</td>
<td>2.5 / 2 log</td>
<td>Regional</td>
<td>5 / 6 log</td>
</tr>
</tbody>
</table>

**Compliance of MBR permeate with:**
- WHO standards for unlimited irrigation
- EU Bathing Water Directive
- California Title 22 Code of Regulations
- ZeeWeed* membrane - supported UF
- lowest proven energy requirement
- simple system operation
- greater than 10 yr membrane life
- 25+ years of experience
- largest installed capacity
- highest manufactured quality
- lifecycle support
- effluent meets reuse standards

*Trademark of SUEZ; may be registered in one or more countries
Leading the Way in MBR

1,900+ full scale MBRs
4+ Billion Gallons Treated Daily

Treating broad spectrum of wastewater

Leaders in Manufacturing

Largest capacity +
Highest quality and reliability
## Largest Awarded MBRs using ZeeWeed

<table>
<thead>
<tr>
<th>Project</th>
<th>Date</th>
<th>ADF/MDF (m$^3$/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henriksdal, Sweden</td>
<td>2018-2022</td>
<td>535,700 / 864,000</td>
</tr>
<tr>
<td>Luofang, China</td>
<td>2017</td>
<td>400,000 / 460,000</td>
</tr>
<tr>
<td>Seine Aval (Achères), France</td>
<td>2017</td>
<td>218,000 / 348,000</td>
</tr>
<tr>
<td>Euclid, OH, USA</td>
<td>2018</td>
<td>83,280 / 250,000</td>
</tr>
<tr>
<td>Beijing Shunyi, China</td>
<td>2016</td>
<td>180,000 / 234,000</td>
</tr>
<tr>
<td>Macau, China</td>
<td>2018</td>
<td>210,000 / 210,000</td>
</tr>
<tr>
<td>Brussels Sud, Belgium</td>
<td>2017</td>
<td>86,000 / 190,000</td>
</tr>
<tr>
<td>Riverside, CA, USA</td>
<td>2016-2017</td>
<td>121,000 / 182,000</td>
</tr>
<tr>
<td>Brightwater, WA, USA</td>
<td>2011</td>
<td>117,000 / 170,000</td>
</tr>
<tr>
<td>Visalia, CA, USA</td>
<td>2016</td>
<td>83,300 / 167,000</td>
</tr>
<tr>
<td>North Las Vegas, NV, USA</td>
<td>2011</td>
<td>94,600 / 132,000</td>
</tr>
<tr>
<td>Ballenger McKinney, MD, USA</td>
<td>2013</td>
<td>56,800 / 132,000</td>
</tr>
<tr>
<td>Assago, Italy</td>
<td>2016</td>
<td>55,000 / 125,000</td>
</tr>
<tr>
<td>Cox Creek WRF, MD, USA</td>
<td>2017</td>
<td>56,800 / 114,000</td>
</tr>
<tr>
<td>Yellow River, GA, USA</td>
<td>2011</td>
<td>69,300 / 111,000</td>
</tr>
<tr>
<td>Cannes (Aquaviva), France</td>
<td>2013</td>
<td>59,100 / 106,000</td>
</tr>
</tbody>
</table>

*In order of maximum daily flow (MDF)*
LEAPmbr’s Success

- Best available MBR technology
- More than **200 projects awarded**
- Over **100 facilities in operation** with LEAPmbr Aeration Technology
- More than **40 existing plants upgraded** to LEAPmbr technology
- Treating over **885 MGD of wastewater**
- Saving the energy to power **320 homes or 300,000 iPads**
Largest LEAPmbr Facilities

- **Henriksdal WWTP, Sweden**
  - ADF 142 MGD & MDF 228 MGD
  - Commissioning 2018-2022

- **Euclid WWTF, Ohio, USA**
  - ADF 22 MGD & MDF 66 MGD
  - Commissioning 2019

- **Brussels Sud WWTP, Belgium**
  - ADF 23 MGD & MDF 50 MGD
  - Commissioned 2017

- **Riverside WQCP, CA, USA**
  - ADF 32 MGD & MDF 48 MGD
  - Commissioned 2016-2017
Henriksdal...building the world’s largest MBR

Location: Stockholm, Sweden
Commissioning 2018 to 2022
ADF 142 MGD & MDF 228 MGD

- One of the fastest growing cities in Europe
- Commitments to Baltic Sea Action Plan and EU Water Directives
- Existing Infrastructure Requiring Upgrades
- Facility Built into a Rock Formation
Henriksdal technical solution

**key challenge:** plant built into rock formation with residential buildings built on top

- biology reconfigured to include phosphorous and nitrogen removal
- membrane system to fit existing secondary clarifiers

Existing Secondary Clarifiers  
Retrofit Solution
City of Abilene, TX turns to indirect potable reuse to maintain reservoirs

Hamby WRF
Start-up: 2015

- Region experiencing chronic draught and population growth putting area reservoirs at 30% capacity
- Residents under strict water use restrictions due to drought
- Discharges more than 7 million gallons of advanced treated wastewater effluent a day into Lake Fort Phantom Hill reservoir
- Awarded the 2016 WateReuse Large Project of the Year
potable reuse in action - Hamby WRF

### Plant Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Influent</th>
<th>Permit</th>
<th>Achieved Quality In MBR Permeate</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>175 – 250 mg/L</td>
<td>7 to 10 mg/L</td>
<td>&lt; 2 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>200 mg/L</td>
<td>15 mg/L</td>
<td>&lt; 2 mg/L</td>
</tr>
<tr>
<td>Ammonia</td>
<td>20 - 35 mg/L</td>
<td>2 to 3 mg/L</td>
<td>&lt; 0.5 mg/L</td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>8 - 10 mg/L</td>
<td>-</td>
<td>&lt; 0.2 mg/L</td>
</tr>
<tr>
<td>SDI</td>
<td>-</td>
<td>-</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>E. Coli</td>
<td>-</td>
<td>126 #/100 mL</td>
<td>&lt; 1 #/100 mL</td>
</tr>
</tbody>
</table>

### Facility Flowsheet

- Grit Removal and Fine Screening → MBR → Ozone → Reverse Osmosis → Biologically Active Filters → Chlorination → De-chlorination and Post Aeration

- Pathogen removal
ZeeWeed MBR California Experience

Trinidad Rancheria – 1,200 gpd
Rancho Malibu – 17,500 gpd
Ventana Inn & Spa – 24,000 gpd
Smith River Rancheria – 25,000 gpd
Big Creek WWTP – 30,000 gpd
Carneros Inn – 37,000 gpd
Valley View Casino – 110,000 gpd
Viejas Casino – 300,000 gpd
Donner Summit PUD – 330,000 gpd
Cache Creek Casino – 350,000 gpd
MWD IPR – 350,000 gpd *
Laguna County WRF – 0.5 MGD
Lancaster WRF – 1.0 MGD
Rio Vista WWTP – 1.0 MGD
Lathrop WWTP – 1.1 MGD
Corona WWTP – 1.1 MGD

Fillmore WWTP – 1.8 MGD
Hi-Desert Water District WWTP – 1.1 MGD (Under Construction)
West Basin WRF 2.0 MGD *
Modesto WWTP – 2.3 MGD
American Canyon WWTP – 2.5 MGD
Hollister WWTP – 5.0 MGD
Ironhouse Sanitary District WWTP – 5.3 MGD
Redlands WWTP – 6.0 MGD
Irvine Ranch WWTP – 11.0 MGD
Visalia WWTP – 18 MGD
Riverside WWTP – 26 MGD
Fresno WWTP – 5.0 MGD
Temecula WWTP – 5.0 MGD *
San Luis Obispo – 6.2 MGD *

* Under Construction
E-Series* MBR for small flows
prefabricated system for easy plug and play implementation

- fast and easy to deploy
- integrated wastewater treatment system
- meets the most stringent effluent requirements
- simple and automated operation
- expedited delivery to meet all schedules

*Trademark of SUEZ; may be registered in one or more countries
Reinforced Membranes Critical to Reliability

- Hollow fiber configuration
- Billions of microscopic pores on the surface
- Pores are barrier to impurities but allow water molecules to pass
- Membrane layer integrated with support braid providing unmatched ruggedness
the ZeeWeed* 500 system
LEAPmbr Process Train

- Biological Reactor
- Membrane Tank
- Air Header
- Permeate Header
- Permeate Pump
- Blower
## MBR Design Criteria vs. Conventional Activated Sludge Plants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional</th>
<th>MBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLSS</td>
<td>&lt; 4000 mg/L</td>
<td>8000 – 12,000 mg/L</td>
</tr>
<tr>
<td>HRT</td>
<td>12 - 20 hrs</td>
<td>2 – 6 hrs</td>
</tr>
<tr>
<td>SRT</td>
<td>&lt; 15 days</td>
<td>10+ days</td>
</tr>
<tr>
<td>Biological sludge yield</td>
<td>&gt; 80%</td>
<td>&lt; 80%</td>
</tr>
<tr>
<td>Bioreactor volume</td>
<td>1x</td>
<td>0.25 to 0.50x</td>
</tr>
<tr>
<td>Clarifier</td>
<td>Primary/Secondary</td>
<td>None (Primary Optional)</td>
</tr>
<tr>
<td>Tertiary treatment</td>
<td>Sand / Membranes</td>
<td>Already UF membrane</td>
</tr>
<tr>
<td>Overall footprint</td>
<td></td>
<td>&gt;4x smaller</td>
</tr>
<tr>
<td>Process stability</td>
<td>Susceptible to upsets / sludge settling limits</td>
<td>High MLSS makes the process stable</td>
</tr>
</tbody>
</table>
Principles of Immersed Membrane Operation

MODES OF OPERATION

1. Filtration (permeation) – 10-12 min
2. Relaxation - 30-45 sec / Backpulse (optional) – 30-60 sec
3. Aeration – LEAP
4. Cleaning
Focus on creating shear along membrane surface via:
• Bubble volume & shape
• Frequency of air release
• Location of air release

Larger bubbles delivered at shorter intervals create more shear and reduce fouling.

The effectiveness of the large bubbles results in less total air volume being required.
Where we were: 10-30 Eco-Aeration

- Air flow to cassette is alternated using cyclic valves
- Two air connections per cassette
- Aeration controlled by varying blower air flow rate + cyclic valves

- Single-stage course bubble diffusor
- Small spherical-cap bubbles
- High volume initial release of air
LEAPmbr Aeration: How it works

- Air flow to cassette is continuous
- Single air connection per cassette
- Aeration controlled by varying blower air flow rate
- No moving parts in cassette or train air headers!

- Multi-stage course bubble diffusor
- Large mushroom-cap bubbles
- Fixed bubble size based on device volume
LEAPmbr aeration technology

LEAPmbr Aeration

Sequential Aeration
Pre-Treatment

- Removal of Damaging/Fouling Substances
- Screening
- Grease/Oil
- Mixed Liquor Characteristics
- pH Adjustment

Protection of Assets is Critical to Smooth Operations
Pre-Treatment

Screening
- 2mm in 2D
- Full standby to cover maintenance downtime
- Installation without bypass
- Regular testing of Mixed Liquor

Oil & Grease
- No free oil
- <10 mg/l non degradable
- <150 mg/l total
- Use separators/DAF to control industrial influent
- Use standard grease/grit in municipal applications

Protection of Assets is Critical to Smooth Operations
Cleaning
(System Reliability = Maintaining Clean Membranes)

1. In-Situ Membrane Cleaning
   operational ease and less module handling

2. Fully Automated Multi-Mode Cleaning Procedures
   reduce operator requirements

3. Regular, Less-Intense Cleaning
   maintain higher membrane permeability, thus able to deal with process upsets

4. Cleaning Flexibility
   process reliability for operators
Membrane Cleaning

1. Maintenance Clean (1/wk)
   - Fully automated and scheduled; ~ 60 minutes
   - Addresses organic fouling
   - 200 mg/L NaOCl (sodium hypochlorite)

2. Recovery Clean (1-2/yr)
   - Restores membrane permeability
   - Operator initiated with witnessed permeability decline to ~70% of start-up; 6-12 hours
   - Addresses organic & inorganic fouling
   - 1,000 mg/L NaOCl and 2,000 mg/L Citric Acid
Maintenance Cleaning

- In-Situ. Membrane Tanks Not Drained. Membranes in mixed liquor.
- Cleaning Solution Backpulsed through membranes in several pulses over 45 minutes
- No airflow. No recirculation flow
- Chemicals: 200 mg/L NaOCl. 1 g/L citric acid
- Municipal Frequency: 2 NaOCl / week. 1 Acid / week (depending on inorganic fouling conditions)
- No disposal of chemicals. Mixed liquor readily consumes the cleaning solution.
Recovery Cleaning

- Membrane Tank Drained and Rinsed
- Chemical solution backpulsed through membranes and tank filled with chemical solution.
- Membranes soaked in cleaning solution for ~8 hours.
- Cleaning Chemicals: 1 g/L NaOCl. 2 g/L Citric Acid (other acids are options)
- Chemical Neutralization: Often Not Required. Spent cleaning solution sent to Head of MBR or out with Waste Sludge.
SUEZ is the RIGHT choice

1. Proven: Pioneered For Harsh Wastewater Environments Using Reinforced Membrane
2. Minimum Risk: Proven Experience in the Municipal Market Leads Assurance that SUEZ can Deliver
3. Value: Minimizes Your Long-term Cost of Ownership
4. Reduced O&M: Completely Automated Operation Including Cleaning Simplifies Plant Operations
5. Schedule: Experienced Project Delivery Team Exceeds Schedule
6. Post-Installation: Large Service Organization Provides Variety of Support and Long-term Client Care
7. Long-Term Partnership: Established and Stable Company that Provides Meaningful Guarantees and Cradle-to-Grave Project Approach