Membrane Applications for Wastewater Re-use in the Middle East
Enviro Arabia 2007
Chris Jeffery
Presentation Outline

• ZeeWeed® UF Technology & Products
• ZENON MBR
• Regional MBR Drivers
• Overview of MBR Developments
• Regional Case Studies
UF Technology
How Membranes Work

- Membrane fibers have billions of microscopic pores on the surface.
- The pores form a barrier to impurities, while allowing pure water molecules to pass.
- Water is drawn through the pores using a gentle suction.
Membranes for Water Treatment

<table>
<thead>
<tr>
<th>Relative Size of Common Materials</th>
<th>Ionics Range</th>
<th>Molecular Range</th>
<th>Macro Molecular Range</th>
<th>Micro Particle Range</th>
<th>Macro Particle Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Salts</td>
<td>0.001 m</td>
<td>0.01 m</td>
<td>0.1 m</td>
<td>1.0 m</td>
<td>10 m</td>
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<tr>
<td>Colloids</td>
<td></td>
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<tr>
<td>Virus</td>
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<tr>
<td>Bacteria</td>
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<tr>
<td>Pin Points</td>
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<tr>
<td>Parasites</td>
<td></td>
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<tr>
<td>REVERSE OSMOSIS (Hyperfiltration)</td>
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<tr>
<td>ULTRAFILTRATION</td>
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<tr>
<td>NANOFILTRATION</td>
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<tr>
<td>MICROFILTRATION</td>
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<tr>
<td>GRANULAR MEDIA</td>
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<tr>
<td>Conventional Pretreatment</td>
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</tbody>
</table>

ZeeWeed® 0.04 µm
ZeeWeed® Products

ZeeWeed® 500d
Reinforced Membranes™

ZeeWeed® 1000
Membrane Filter Media™
ZeeWeed® Hollow Fibre Membranes

ZeeWeed® 500
Diameter (1.9/0.8 mm),
Extremely solids tolerant

ZeeWeed® 1000
Diameter (0.8/0.47 mm),
High packing density
ZeeWeed® 500d Module

Modules are composed of thousands of membrane fibers.
ZW 500 Membrane System
ZW 1000 Membrane System
Principles of ZeeWeed® Immersed Membranes

Air → Permeate ←

Membrane Fiber
Membrane Cassette
Mixed Liquor

Aeration
Wastewater Treatment

For Water Reuse
MBR or Tertiary
Tertiary Filtration vs. MBR

Conventional Process:

- Influent
- Aeration basin
- Secondary clarifier
- Sand filter
- Effluent to discharge
Tertiary Filtration vs. MBR

Conventional

Influent → Aeration basin → Secondary clarifier → Sand filter → Effluent to discharge

Tertiary Filtration

Influent → Aeration basin → Secondary clarifier → Membrane filtration → High quality effluent to reuse or RO feed
Tertiary Filtration vs. MBR

Conventional:
Influent → Aeration basin → Secondary clarifier → Sand filter → Effluent to discharge

Tertiary Filtration:
Influent → Aeration basin → Secondary clarifier → Membrane filtration → High quality effluent to reuse or RO feed

Membrane Bioreactor:
Influent → Aeration basin → Membrane filtration → High quality effluent to reuse or RO feed
Membrane Bioreactor (MBR)
For Water Reuse
Membrane Bioreactor (MBR)

Activated Sludge Process

Membrane Filtration

Stable Biological Treatment Process

Absolute Solids Separation
A Basic MBR Production Train

1. Biological reactor
2. Membranes
3. Permeate pump & air blower
4. Control panel
5. Permeate & air piping
Overall ZeeWeed® MBR Design
Regional MBR Drivers

- Effluent Quality
- Reduced Plant Footprint & Lower Civil Costs
- High Cost of Alternative Water Sources
- Process Advantages:
  - complete control of sludge age
  - does not depend on sludge settling characteristics
Advantages of UF membranes

*High-quality effluent*

<table>
<thead>
<tr>
<th>Effluent Parameters</th>
<th>Typical Values</th>
<th>Achievable Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$</td>
<td>&lt; 2 mg/L</td>
<td>Typically n.d.</td>
</tr>
<tr>
<td>TSS</td>
<td>&lt; 2 mg/L</td>
<td>Typically n.d.</td>
</tr>
<tr>
<td>NH$_4$ - N</td>
<td>&lt; 1 mg/L</td>
<td>&lt; 0.5 mg/L</td>
</tr>
<tr>
<td>TN</td>
<td>&lt; 10 mg/L</td>
<td>&lt; 3 mg/L</td>
</tr>
<tr>
<td>TP</td>
<td>&lt; 0.3 mg/L</td>
<td>&lt; 0.1 mg/L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>&lt; 0.3 NTU</td>
<td>&lt; 0.1 NTU</td>
</tr>
</tbody>
</table>

... and physically disinfected!
Advantages of UF membranes

**Compliance with global standards**

UF permeate in compliance with:

- WHO standards for unlimited irrigation
- International Maritime Organization bacteriological limits
- EU bathing Water Directive
- California Title 22 Code of Regulations

UF: the best approach to meet the tightest effluent quality requirements
California Title 22, Chapter 4  
Compliance with global standards

The most stringent standards for wastewater reuse across the U.S. (and possibly the world)  
Regulations adopted in 1978 by CDHS (California Department of Health Services)  
• Recycled water quality standards  
• Reliability & redundancy of recycled water treatment plants  
• Tertiary treatment + disinfection  
 Standards  
• Strategy favoring the beneficial reuse of water to the maximum extent practical  
• Bacteriological standards based on the expected degree of public contact with recycled water

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Maximum</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity (NTU)</td>
<td>&lt; 2</td>
<td>&lt; 10</td>
<td>&lt; 5 (5% of time in any 24 hr period)</td>
</tr>
<tr>
<td>Total coliforms (ufc/100 mL)</td>
<td>&lt; 2.2</td>
<td>&lt; 240</td>
<td>&lt; 23 in any 30 day period</td>
</tr>
<tr>
<td>Fecal coliforms (ufc/100 mL)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Key MBR Driver - Reduced Footprint

ZeeWeed® MBR Upgrade (11 MGD)  Existing Line A (6.3 MGD)
## Costs of Producing Water from Secondary Effluent and from Seawater

<table>
<thead>
<tr>
<th>Component</th>
<th>Units</th>
<th>A: from CAS effluent</th>
<th>B: from seawater</th>
<th>Ratio (B/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure &amp; pretreatment</td>
<td>$/m^3/d</td>
<td>161</td>
<td>320</td>
<td>1.99</td>
</tr>
<tr>
<td>RO</td>
<td>$/m^3/d</td>
<td>321</td>
<td>624</td>
<td>1.94</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$/m^3/d</td>
<td>482</td>
<td>944</td>
<td>1.96</td>
</tr>
<tr>
<td><strong>Total Life cycle costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>$/m^3</td>
<td>0.07</td>
<td>0.24</td>
<td>3.43</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$/m^3</td>
<td>0.21</td>
<td>0.38</td>
<td>1.81</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$/m^3</td>
<td>0.28</td>
<td>0.62</td>
<td>2.21</td>
</tr>
</tbody>
</table>
Developments In MBR
Total Capital Costs

![Graph showing total capital costs vs. flow rate in m$^3$/d. The graph compares different technologies, including CAS, MBR, and CAS-TF.]
Total O&M Costs

Flow rate, m³/d

CAS
MBR
CAS-TF
Total Life-Cycle Costs

![Graph showing Total Life-Cycle Costs vs. Flow rate, m³/d for different processes: CAS, MBR, CAS-TF. The costs decrease as flow rate increases.]
Capital Cost Developments
ZeeWeed® 500 Cassette Evolution

1993

ZW-145  ZW-150  ZW-500a  ZW-500c  ZW-500d

2003
Operational Cost Developments
MBR Energy Users

- Anoxic Mixers
- RAS Flow
- Biological Process Aeration
- Membrane Aeration
- Permeate Flow

34 / GE /
MBR Energy Users

- Bio Process Aeration: 42%
- Membrane Aeration: 34%
- RAS Pumping: 10%
- Permeate Pumping: 4%
- Anoxic Mixing: 9%
- Misc: 1%
Reduction of Aeration Energy

- Effect of MLSS - Optimize Footprint & Energy
- Reduction of Membrane Air Scour Power – Cyclic Aeration
Effect of MLSS on Alpha Factor

Optimizing Energy Efficiency

Biological process aeration

• Select MLSS to optimize OTE
  – Alpha factor decreases at higher MLSS
  – Limitation on OUR at higher MLSS

• Fine bubble aeration in bioreactor

![Graph showing the relationship between MLSS and OTE]
Bio-Process NPV vs. MLSS Concentration

![Graph showing the relationship between Bioreactor Capital, Process Aeration NPV, and the total NPV (Bioreactor Capital + Process Aeration NPV) with respect to MLSS concentration. The graph indicates how the NPV changes as the MLSS concentration varies.]
Bio-Process NPV vs. MLSS Concentration

Design

- $0.04 / kWhr
- $0.06 / kWhr
- $0.08 / kWhr

MLSS (mg/L)
Membrane Aeration

- Optimize membrane submergence to reduce blower discharge pressure
- Effective scouring with course bubble aeration
- Optimized cyclic aeration based on flow

US Patent 6,245,239
10/30 Aeration at ADF

- Optimized cyclic aeration based on flow
- Maintain 10/10 Aeration at or above ADF
- Run at 10/30 Aeration below ADF
- 50% Savings compared to 10/10 = 7-10% LCC
10/10 Sequential Aeration
- 4 blowers on
- each blower sized to aerate ½ of one train

Note – Airflow is blue
10/30 Sequential Aeration

- 2 blowers on
- each blower sized to aerate ½ of one train
- same instantaneous air flow rate as 10/10 BUT ½ the average

Note – Airflow is blue
Main Reference Plants in the Middle East
List of Main Plants

• Buraida Upgrade, KSA (Fe/Mn Filtration)
• Jeddah Industrial City, KSA (Tertiary Treatment)
• Doha West, Qatar (Tertiary Treatment)
• Lusail, Qatar (MBR)
• Dubai Sports City, UAE (MBR)
Buraida Upgrading, Qassim, KSA
Water Treatment Plant

- Capacity

  - 100,000 m³/day (26.4 MGD) Ultimate Capacity
  - 85,000 m³/day (22.5 MGD) Initial Capacity

Plant is designed for Iron/Manganese & Radium Removal for RO Pre-treatment

- Effluent Quality:
  - Turbidity < 0.1-0.3 NTU
  - SDI < 2-3
Buraida Upgrading-Cont’d

System Configuration:

- Seven trains each with seven ZW 1000 V3 Cassettes
- Total number of elements Initial: 2,142; Ultimate 2,499
- End User: Qassim Water Authority
- Expected Commissioning Date: June 2007
Jeddah Industrial City, KSA - Tertiary Treatment

• Capacity
  - 14,640 m³/day (3.86 MGD)

• Feed Water Quality:
  - BOD/TSS 10/10 mg/l  Turbidity 2-3 NTU

• Effluent Quality:
  - Turbidity < 0.2 – 0.5 NTU  -SDI < 3.0
Jeddah Industrial City, Cont’d..

- System Configuration:
  - Three (3) Membrane Trains, Two (2) Cassettes in Each Train
  - Each Cassette has 51 Zee Weed 1000 V3 Elements
  - In operation since January 2006
DOHA WEST-Doha, Qatar
Tertiary Treatment

Capacity
- 135,000 m³/day (35.7 MGD)

Feed Water Quality:
- TSS 5-10 mg/l (Weekly Max)

Effluent Quality:
• Turbidity < 0.1 – 0.5 NTU
• Nematode Eggs >4 Log Removal
DOHA WEST, Cont’d…

- System Configuration:
  - Seven (7) Membrane Trains, Six (6) Cassettes per Train
  - Total number of Membranes is 3,528
  - Inst. Design Flux: 45 Imh (N Mode), 53.6 Imh (N-1 Mode)
- UF Effluent is used for Irrigation
- Expected Commissioning Date: December 2007
LUSAIL MBR System
Doha, Qatar

• (Ultimate) Design Flow
  • 61,300 m³/d wastewater flow
• Feed Water Quality:
  - Sanitary Waste
• Effluent Quality:
  • Irrigation Water Quality
Lusail MBR System, Cont’d…

Bioreactor
- 4 (four) bioreactors @ 3250 m³ each (for final stage)

Membrane Tanks
- Staged expansion of plant with 3/4/7/8 membrane trains
- Each train equipped with 5 (five) ZeeWeed 500d trains, using 64 Element Cassettes
LUSAIL, Cont’d…

• System Configuration (Phase 4)
  - Eight (8) Membrane Trains, Five (5) Cassettes per Train
  - Total number of Membranes is 2,456
  - Net design flux: 32.9 lmh (N Mode), 37.6 lmh(N-1 Mode)
• UF Effluent is used for Irrigation
• End User: Qatari Diyar Real State
• Expected Commissioning Date: December 2007 (Phase 1)
Dubai Sports City STP

ADF: 25,000 m³/d

Commission Date: Expected Jan 2008

Partnership with local contractor

MDF is 30,000 m³/d

Phased approach with 2/3 capacity installed

6 trains at buildout

Effluent used as TSE for irrigation

Evaluated Bid
Thank You!............. Questions?