GE Water & Process Technologies

Simple and Reliable Membrane Bioreactor Technology for Wastewater Treatment
What is ZeeWeed MBR?

- Advanced technology that combines ultrafiltration (UF) membranes with biological treatment
- Brings conventional clarification, aeration and filtration together into a single step
Membrane Bioreactor (MBR) Technology
Chronology of Significant Events

- **MID 1960’s**
  - Dorr-Oliver Membrane Sewage Treatment System

- **1975**
  - Thetford Corp.
  - Developed Cycle-Let Recycling of Flushwater

- **1989**
  - ZENON Industrial System for GM (ZENOGEM)

- **1994**
  - ZENON purchased Thetford

- **1996**
  - ZENON Municipal 1ST Municipal Sewage System

- **2005**
  - ZENON selected to supply the world’s largest membrane bioreactor to King County, WA (38 MGD)
  - To be completed in 2010

*As of March 2005*
Membranes are Rapidly Replacing Conventional Technology

**Conventional Treatment**
- 19th century technology
- Large land requirement
- Coarse filtration, no physical barrier
- Need multiple steps for coarse filtration
- Labor and chemical intensive
- Dependent on chlorine for disinfection

**ZeeWeed Membrane Treatment**
- Modern and continuously improving
- Compact footprint; Allows for expansion
- Physical barrier means higher quality water at all times
- Single step provides simpler operation
- Fully automated with minimal chemicals
Treated Water Quality Exceeds the World’s Toughest Standards – Current and Future

World Health Organization’s Standards for Unlimited Irrigation

European Union’s Bathing Water Directive

California’s Title 22 Code of Regulations

US EPA Turbidity Limit for Drinking Water is 0.3 NTU

Treated Wastewater from a ZENON system is <0.5 NTU
ZeeWeed = *Consistent* High Quality Effluent

<table>
<thead>
<tr>
<th>Achievable ZeeWeed Treatment Results</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOD$_5$</strong></td>
<td>&lt; 2 mg/L</td>
</tr>
<tr>
<td><strong>TSS</strong></td>
<td>&lt; 1 mg/L</td>
</tr>
<tr>
<td><strong>NH$_3$-N</strong></td>
<td>&lt; 0.05 mg/L</td>
</tr>
<tr>
<td><strong>TN</strong></td>
<td>&lt; 3 mg/L*</td>
</tr>
<tr>
<td><strong>TP</strong></td>
<td>&lt; 0.05 mg/L*</td>
</tr>
<tr>
<td><strong>Turbidity</strong></td>
<td>&lt; 0.1 NTU</td>
</tr>
<tr>
<td><strong>Fecal Coliform</strong></td>
<td>&lt; 2.2 CFU/100</td>
</tr>
<tr>
<td><strong>SDI</strong></td>
<td><strong>&lt;</strong></td>
</tr>
</tbody>
</table>

* * With appropriate biological design  
** After disinfection

ZeeWeed MBR selected by the City of Corona, CA for its small footprint and the ability to meet Title 22 discharge regulations.

Reusing the majority of their existing infrastructure, the city of Woodstock, GA converted a 0.5 MGD (1,893 m$^3$/d) SBR into a 2 MGD (7,570 m$^3$/d) ZeeWeed MBR.
Reinforced Membranes are the Key to Superior Effluent Quality

Hollow strands of porous plastic fibers with billions of microscopic pores on the surface

The pores are thousands of times smaller in diameter than a human hair

Pores form a physical barrier to impurities but allow pure water molecules to pass

Clean water is drawn to the inside of fiber by a gentle suction
ZeeWeed MBR Features & Benefits

**Physical UF barrier** produces high quality effluent suitable for direct non-potable reuse

**Unmatched fiber ruggedness** ensures long membrane life

“**Self-healing” fibers** eliminate catastrophic membrane failures

**Multiple cleaning techniques** maintains long-term, peak system performance

**Compact design** minimizes land acquisition and construction costs

**Proven system performance** in hundreds of municipal and industrial applications provides you with peace of mind

Hollow fibers operate under a gentle vacuum, drawing treated effluent from the outside to the inside.
The Best Available Technology for Virtually All Wastewater Treatment Applications

Greenfield Plant
Enclose and blend your plant with the local surroundings
Cauley Creek, GA

Water Reclamation
Treat and reuse your plant’s effluent for irrigation
American Canyon, CA

Retrofits
Double your plant’s capacity within the same footprint Traverse City, MI
Proven Solutions for Plants of All Sizes

GE has the proven experience to deliver MBR plants of any size, from small pre-engineered, quick delivery systems to the world’s largest operating plants.

< 2,000 GPD

> 30 MGD
# Total GE MBR Plants

<table>
<thead>
<tr>
<th>Application</th>
<th>Number of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America Municipal</td>
<td>52</td>
</tr>
<tr>
<td>International Municipal</td>
<td>60</td>
</tr>
<tr>
<td>North America Land Development Systems (LDS)</td>
<td>131</td>
</tr>
<tr>
<td>International LDS</td>
<td>18</td>
</tr>
<tr>
<td>North America Industrial</td>
<td>44</td>
</tr>
<tr>
<td>International Industrial</td>
<td>115</td>
</tr>
<tr>
<td>Shipboard/Military</td>
<td>17</td>
</tr>
<tr>
<td><strong>Total MBR Plants</strong></td>
<td><strong>437</strong></td>
</tr>
</tbody>
</table>

* 2007 values
**Largest Operating**

MBRs use ZeeWeed

<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syndial, Italy</td>
<td>12.4 mgd (ADF/MDF)</td>
</tr>
<tr>
<td>NordKanal, Germany</td>
<td>4.4 mgd / 11.9 mgd</td>
</tr>
<tr>
<td>Tempe Kyrene, AZ</td>
<td>9 mgd / 11.7 mgd</td>
</tr>
<tr>
<td>Brescia, Italy</td>
<td>11.2 mgd (ADF/MDF)</td>
</tr>
<tr>
<td>Traverse City, MI</td>
<td>7.1 mgd / 10.2 mgd</td>
</tr>
<tr>
<td>Redlands, CA</td>
<td>6.0 mgd / 6.6 mgd</td>
</tr>
<tr>
<td>Cauley Creek, GA</td>
<td>5.0 mgd / 6.2 mgd</td>
</tr>
<tr>
<td>Delphos, OH</td>
<td>3.8 mgd / 6 mgd</td>
</tr>
<tr>
<td>Buxton, UK</td>
<td>4.4 mgd</td>
</tr>
<tr>
<td>M City, China</td>
<td>4.0 mgd</td>
</tr>
<tr>
<td>American Canyon, CA</td>
<td>2.5 mgd / 3.8 mgd</td>
</tr>
<tr>
<td>Konzen, Germany</td>
<td>3.7 mgd</td>
</tr>
</tbody>
</table>

*As of January 2007, in order of peak daily flow*
15 of 20 Largest MBRs Awarded* use ZeeWeed

Brightwater, WA
Johns Creek, GA
Cleveland Bay, Australia
Al Ansab, Muscat, Oman
Beixiaohe, China
Peoria, AZ
Lusail, Qatar
Delphos, OH
San Pedro, Spain
Syndial, Italy
NordKanal, Germany
Tempe Kyrene, AZ
Brescia, Italy
C City, Korea
 Traverse City, MI
Gainesville, GA
Henderson, NV
Hilversum, the Netherlands
Loudon County, VA
Hallsdale / Beaver Creek, TN
North Kent, MI

31 mgd / 38 mgd
10.9 mgd / 24.7 mgd
7.7 mgd / 19.8 mgd
14.8 mgd / 20.6 mgd
15.8 mgd / 20.6 mgd
10 mgd / 20 mgd
15.9 mgd (ADF/MDF)
3.8 mgd / 12 mgd
5.2 mgd / 12.6 mgd
12.4 mgd (ADF/MDF)
4.4 mgd / 11.9 mgd
9 mgd / 11.7 mgd
11.2 mgd (ADF/MDF)
10.6 MGD – MRC SADF
7.1 mgd / 10.2 mgd
4.6 mgd / 10.1 mgd
8 mgd / 9.6 mgd
9.5 mgd – Koch / Puron
5.0 mgd / 9.4 mgd
6 mgd / 9.3 mgd
6 mgd / 9.3 mgd

*As of January 2007, in order of peak daily flow
Over 400 MGD-years of MBR Experience

(MGD-years = plant capacity x Years in Operation)

This means we offer the most:

• R&D experience;
• Membrane manufacturing experience;
• System and process design experience;
• Commissioning experience;
• Operation and maintenance experience;
• Service and support experience;
• Value.
What is a membrane?

Membranes are engineered thin barriers or films of material that allow certain substances to pass by a size exclusion mechanism related to the size of the pores on the membrane surface.
Membrane Filtration

Conventional Pretreatment
Giardia and Cryptosporidium

Giardia (4-14 micron)

Cryptosporidium (4 - 6 microns in diameter)
The ZeeWeed 500 – UF Membrane

Reinforced membrane structure
PVDF Chemistry

• Oxidant resistant
  (500,000 ppm-hr Cl$_2$)
• Wide pH range
  —Filtration: 5 to 9.5 pH
  —Cleaning: 2 to 11 pH

Compatible with coagulants & PAC

NSF61 certified
ZeeWeed 500 – The Most Robust Membrane System

• Strongest fiber in the industry
  – Single fiber can hold over 50 kg
  – Majority of modules ever installed are still in service (first membrane installed in 1993)

• Highest solids tolerance with most effective backwash
  – Can operate with < 1.0 mg/L TSS to 50,000+ mg/L MLSS (sludge thickening)

• No need for pre-clarification

• Ability to handle water quality upsets

• Conservative design approach
The ZeeWeed 500 Module

A cassette contains from 4 to 64 ZeeWeed modules

Permeate is drawn from both top & bottom header

Aerators are attached to the cassette frame, not the elements themselves

The cassette frames provide the support for the 500 modules
The ZeeWeed 500 cassette

Central Permeate Header

Central Permeate Collection Tubes (top & bottom for 4 elements)

Air Piping

Aerator Tubes
Building Block Design

Membrane Modules are simply inserted into frames to form a Membrane Cassette.

ZeeWeed Reinforced Membrane modules and cassettes are built tough to provide a long and reliable operating life in harsh MBR conditions.
The ZeeWeed 500 System
ZeeWeed MBR Technology
ZeeWeed Membrane Bioreactor

Hi-Rate Bioreactor
- large capacity throughput
- compact footprint
- advanced treatment
- simpler more reliable process

Absolute/Positive Filter
- high degree of organisms/solids control
- consistently high effluent quality
- lower operator attention - less components

Feed

10,000 to 15,000 mg/l

Concentrate Return

Sludge for Disposal

Filtrate (Treated WW)
Principles of ZeeWeed Immersed Membranes
Basic MBR Production Train

1. Biological reactor
2. Membranes
3. Permeate pump & air blower
4. Control panel
5. Permeate & air piping
Trains are Simply Multiplied to Meet Capacity Requirements

Above example: 30 MGD peak / 15 MGD average daily flow MBR plant design with an approximate footprint of 276 ft long x 181 ft wide.
Significant Footprint Reduction

Membrane bio-reactor plant

Conventional plant
Ideal for Expansion or Retrofit of Existing Plants

Modular design allows for easy expansion

Retrofit existing sand filters or clarifiers

- Convert existing treatment plant to a high-efficiency membrane process
- Reduced capital costs through use of existing infrastructure
- Increase capacity by 3 – 5 times within existing footprint
- Upgrade effluent to reuse quality

Brescia, Italy - Membranes retrofit into existing activated sludge treatment lines

City of Duvall, WA – MBR replaced and expanded existing conventional system, using existing tanks for part of the biological process
Enhanced Nutrient Removal (ENR)

ZeeWeed MBR operates at high solids concentrations of 8,000-12,000 mg/L, optimizing the nitrification and de-nitrification processes.

- Sludge retention times are extended to ensure almost complete nitrification.
- Can be designed with pre- and post-anoxic zones, and chemical addition for phosphorus removal.

Loudon County, VA

- 5 MGD WWTP designed to achieve nitrification, denitrification and biological phosphorous removal.
- Designed to meet the following criteria:
  - COD 10 mg/L
  - TN 3 mg/L
  - TP 0.1 mg/L

Anaerobic zones can be incorporated into the process for biological uptake of phosphorous.
ZeeWeed MBR Design Considerations

1. Responsible Flux Design
2. Pretreatment Requirements
3. Biological Treatment System
4. Membrane System
5. Permeate Collection & Discharge System
## Design Flux Selection

<table>
<thead>
<tr>
<th>Conservative</th>
<th>Aggressive</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Long term reliability</td>
<td>• Less reliable system</td>
</tr>
<tr>
<td></td>
<td>➢ potential for failure</td>
</tr>
<tr>
<td>• Long membrane life</td>
<td>• Shorter membrane life</td>
</tr>
<tr>
<td></td>
<td>➢ high rate of fouling</td>
</tr>
<tr>
<td>• Higher capital costs</td>
<td>• Lower initial capital costs</td>
</tr>
<tr>
<td></td>
<td>➢ less membrane area provided</td>
</tr>
<tr>
<td>• Higher operating costs?</td>
<td>• Lower initial operating costs?</td>
</tr>
</tbody>
</table>
Pretreatment Requirements

Screening:

- Protecting your assets
- Common to all MBR systems
- 2 mm in 2-D
- Center feed screens

Optional: grit removal, primary clarification.

Oil & grease removal for some industrial applications
Acceptable Fine Screens

Internally Fed Rotary Drum Screen
- South Shore, AB
- Cabezon, NM
- Mariposa, NM
- Hollister, CA
- North Kent, MI

In-channel Rotary Drum Screen
- Nordkanal, Germany
- Schilde, Belgium
- Brescia, Italy
- Jackson, OH
- Beaver Creek, TN
Acceptable Fine Screens

Rotating Brush Screen

Traveling Band Screen
Hollow Fibre vs. Flat Sheet
Fine Screening Ensures Membrane Reliability

Typical cassette.
2 mm rotary drum screen
2 years of operation
Good screen performance!
Biological Treatment System

Aerobic, anoxic, anaerobic zones
• Combination depends on treatment goals
• Aeration or mixing

Mixed liquor recirculation

Surface wasting for scum and foam control
Biological Process Aeration

- Select MLSS to optimize oxygen transfer efficiency and construction costs
- Design with anoxic zone to recover alkalinity and reduce energy consumption
- Fine bubble aeration
Membrane System

Tools for maintaining the permeability of the ZeeWeed membranes:

- Aeration
- Comprehensive Cleaning Toolbox
ZeeWeed Aeration

Rising air bubbles mechanically scour membrane surface

Defined membrane fibre slack encourages fibre movement, sloughing off surface deposits
Comparative Energy Usage in MBRs

Bio Process Aeration: 42%
Membrane Aeration: 34%
RAS Pumping: 10%
Permeate Pumping: 4%
Anoxic Mixing: 9%
Misc: 1%
Intelligent Aeration Controls

Principle - Vary aeration frequency in response to solids loading on membranes.

- drastically reduces operation costs by up to 75% while ensuring superior plant performance under all conditions.

10/10 Sequential Aeration – above AD Flux

10/30 Eco-aeration – below AD Flux

(US Patent 6,245,239)
10/10 Cyclic Aeration Cycle

10 seconds of air into pipes A and C
10 seconds of air into pipes B and D
10/30 Eco-aeration Cycle

10 seconds of aeration in pipe A
30 seconds of rest in pipe B
30 seconds of rest in pipe C
30 seconds of rest in pipe D

75% Savings in Blower Energy
Comprehensive Cleaning Toolbox

**Backpulse with permeate**
- To address unusual sludge filterability

**Regular maintenance cleans**
- Fully automated
- Regular less-intense cleaning

**Recovery Cleans**
- Maintain as new membrane permeability
- Fully automated
- Intense clean (2 times per year)
ZeeWeed Cleaning Philosophy

**Hollow Fibre**
Easy backwash favors frequent maintenance cleaning

**Flat-sheet**
Low back-pressure limit dictates recovery cleaning regime

**Benefits of hollow fibre**
- Clean-in-place is fully automated
- Membranes are always clean and ready to meet peak flow
- Backwashing (without chemicals) enhances performance with difficult sludges
Permeate & Backpulse Pump Options

Split Case Centrifugal
• Goulds, Flowserve

End Suction Centrifugal
• Goulds, Flowserve

Rotary Lobe
• Borger
• Vogelsang
• Lobeline

Gravity
Brescia Permeate/Backpulse Pumps
Reversible Pumps

Same pump performs several functions:

- Permeation
- Backpulse
- Cleaning

Simplifies Design & Operation:

- No separate backpulse pumps
- No separate cleaning pumps
- No air separation equipment
Reversible Pump Installations