MemJet
Membrane Bioreactor Technology

USFilter, Jet Tech Products
Presentation Outline

- Membrane Filtration Basics
- MBR Evolution
- Value of MBR Technology
- USFilter MBR design
- Pilot Capabilities
- Demonstration Plant
Membrane Filtration Basics
Low-Pressure Polymeric Membrane

Mixed Liquor
MLSS 5,000 – 16,000 mg/l

Permeate
BOD < 5 mg/l
TSS < 1 mg/l
Turbidity < 0.2 NTU

Flow
Membrane Filtration Spectrum

- **Reverse Osmosis**
- **Nanofiltration**
- **Ultrafiltration**
- **Microfiltration**

Transmembrane Pressure Decreasing
Pore Size Increasing

<table>
<thead>
<tr>
<th>Membrane Separation Process</th>
<th>Reverse Osmosis</th>
<th>Nanofiltration</th>
<th>Ultrafiltration</th>
<th>Microfiltration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Common Materials</td>
<td>Salts</td>
<td>Carbon Bk.</td>
<td>Paint Pigments</td>
<td>Human Hair</td>
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<tr>
<td></td>
<td>Pyrogens</td>
<td>DNA. Viruses</td>
<td></td>
<td>Sand</td>
</tr>
<tr>
<td></td>
<td>Metal Ions</td>
<td>Tobacco Smoke</td>
<td></td>
<td>Mist</td>
</tr>
<tr>
<td></td>
<td>Vitamin B12</td>
<td>Bacteria</td>
<td></td>
<td>Coal Dust</td>
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<tr>
<td></td>
<td>Sugar</td>
<td>DNA. Viruses</td>
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<td>Bacteria</td>
</tr>
<tr>
<td></td>
<td>Colloids</td>
<td></td>
<td></td>
<td>Pollens</td>
</tr>
<tr>
<td></td>
<td>Atoms</td>
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<td></td>
<td>Pollens</td>
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<td></td>
<td></td>
<td>Pollens</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle Type</th>
<th>Ions</th>
<th>Molecules</th>
<th>Macro Molecules</th>
<th>Micro Particles</th>
<th>Macro Particles</th>
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<tr>
<td>Micrometers (Log Scale)</td>
<td>0.001</td>
<td>0.01</td>
<td>0.1</td>
<td>1.0</td>
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Filtration in the 0.1 micron range is the most widely used membrane type in wastewater treatment applications.
**Definitions**

- **Immersed membrane**: Membrane submerged directly in process, outside to inside flow under vacuum

- **Flux**: Loading rate of flow per membrane surface area in GPD/Ft² (“GFD”)  

- **TMP**: Pressure across membrane surface in PSI

- **Permeability**: Flux divided by the pressure GFD/PSI

- **Packing Density**: Area of fibers divided by module area

- **Lumen**: Open center of the fiber

- **Backpulse**: Reverse flow with change from vacuum to pressure on membrane

- **Maintenance Clean**: Short term, in-process cleaning procedure

- **CIP**: Clean-In-Place chemical clean process
Four-Module Pilot

1.5 meters
Membrane Configurations

- **Polymer Monolith**
  - Single material (homogeneous)
  - Self-supporting
  - Single manufacturing process
  - Hollow fiber configuration only

- **Laminate**
  - Multiple materials (non-homogeneous)
  - Multiple manufacturing processes
  - Supported
  - Hollow fiber or flat-sheet configuration
Polymer Monolith

- Symmetrical
  - Pore structure similar through membrane depth
  - Microfiltration only

- Asymmetrical (used in MBR)
  - Also called “skin” membranes
  - Very thin, tight membrane layer at surface with macroporous substructure
    - Microfiltration
    - Ultrafiltration
Laminated Membrane
Laminated Membrane

- Membrane is applied to a substrate or backing for support
- Mechanical bond is critical
## Membrane Comparison

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Polymer Monolith</th>
<th>Laminate</th>
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<tbody>
<tr>
<td>Materials</td>
<td>1 (Homogeneous)</td>
<td>2 or more</td>
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<tr>
<td>Tensile Strength</td>
<td>Low</td>
<td>High</td>
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<tr>
<td>Radial Strength</td>
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<td>Low</td>
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<tr>
<td>Delamination Potential</td>
<td>None</td>
<td>Yes</td>
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<td>USFilter Configuration</td>
<td>Yes</td>
<td>No</td>
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Membrane Bioreactor Evolution
Tubular Membrane Feed & Bleed MBR’s

Commercialized Mid 1970’s

Bioprocess

Pump

Feed

Recirculation

Bleed

Permeate
Cross Flow Tubular

*Low surface area - high energy consumption*

- Turbulent crossflow 17 fps
- PVC outer shell
- Porous membrane support

Permeate
Cross Flow Tubular

Low surface area - high energy consumption

1"

Turbulent crossflow 17 fps

Porous membrane support

High Pressure (70 psi)

PVC outer shell

Permeate

Cross Flow
Immersed Membrane MBR

*High surface area – reduced energy consumption*

Commercialized 1990’s

- Bioreactor
- Recirculation
- Permeate
- Low vacuum pressure (up to 7.5 psi)
Typical MBR Layout

- Fine screening
- Anoxic Basin
- Aeration Basin
- Aerobic Digester
- Membrane Operating System
Typical MBR Layout

Fine screening

Aeration Basin

Anoxic Basin

Aerobic Digester

Membrane Operating System

Membrane Operating System

Typical MBR Layout
Benefits of Immersed MBR Technology
Value of MBR technology over conventional processes

- Fewer process steps to achieve comparable effluent quality
- Eliminates sludge settleability problems
- Small Footprint
- Modular expansion capability
- Reduced sludge yield
- High quality effluent
  - Low effluent turbidity
  - Excellent nutrient removal capability
  - High rejection efficiency of organic constituents, solids and micro-organisms
  - Uncompromised effluent in upset conditions
“Less is More”

Conventional Process Using Low Pressure Membranes

Integrated Membrane Bioreactor
Integrated Membrane Bioreactor Process

HIGH MLSS

Conventional

Integrated Membrane Bioreactor

2,000 - 4,000 mg/l

8,000 - 16,000 mg/l

F = BOD Loading

M = MLSS X Aeration Vol.

BOD X Daily Flow
Integrated Membrane Bioreactor Process

TANK VOLUME
Activated Sludge Process

100%  25%

CONVENTIONAL    MBR

Small Footprint
Integrated Membrane Bioreactor Process

Conventional

Integrated Membrane Bioreactor

60-100%

40%

Low Sludge Yield
Where do MBR’s fit?

- Advanced phosphorus and nitrogen removal
- Effluent reuse and recharge
- Limited footprint
- Upgrade of existing plants
  - Increased flow in existing tankage
  - Restricted effluent requirements
  - Nutrient reduction
  - Add-on to existing biological process
USFilter

MemJet

MBR Technology
Temperature decrease increases viscosity.
Managing the Membrane Environment

Keys to success:

- Fine screening
- Controlling fluid transfer

Failure results in:

- Solids packing around fibers
- High Fluid Viscosity around fibers
- Loss of Permeability (Fouling)
- High Maintenance
USFilter MBR Design

- Managing the Membrane Environment
  - Fluid Renewal System (Two-Phase Jet)
  - Separated Membrane Process

- Maintenance Procedures
  - Backpulse
  - Maintenance Clean
  - CIP

- Integrity Test Capability
  - Ability to predict turbidity breakthrough, identify source, and repair
Features & Benefits of USFilter MBR

- Controlled environment around membrane system
- Positive fluid transfer into fiber bundles
- Uniform distribution of flow and solids
- Cross-flow dynamics minimize energy consumption
- Automated, in-place, membrane cleaning process (membrane removal unnecessary)
- Safe environment for plant operators
- Flexibility in biological process selection
Partitioned fiber bundles

Narrow fiber bundles provide excellent fluid transfer within the entire module.

30% less aeration energy

Two-Phase Jet
Bottom of Module

Air & Mixed Liquor “Ports”

Divides even distribution of air & mixed liquor within module

Separator divides module into smaller partitioned bundles

Membrane fibers are aerated with air and mixed liquor
Membrane Operating System

- Uniform air/mixed liquor distribution across membranes
- Aerated liquor, overflow & gas removal
- Membranes

Aerated liquor & air operated independently
Combination of Cross-Flow Dynamics and Dead-End Filtration
Factors impacting cleaning interval

**Prescreen:** Poor prescreen will cause fibers and debris to be trapped in fiber bundles restricting movement

**Free oils and greases:** These can coat the membranes and decrease flux. Standard municipal wastewater not a problem.

**Polymers:** High concentration of polymers can coat membranes and decrease flux.
Permeability Curve - Flux vs. TMP

Impact of fouling layer on permeability

New / clean membrane

Membrane with fouling layer

Stable operating zone

Maintenance cleans slow decay

Membrane needing CIP
Flow Control Operation

TMP vs. Time

Flow stable

Pressure increases as membrane fouls

CIP
Membrane Maintenance

- Backpulse
- Maintenance Clean
- Relaxation
- Clean-In-Place (CIP)
Completely Automated
Every 12-20 minutes
15 second duration
Reverse flow utilizing filtrate pumps
Jet with mixed liquor and air remains in operation
Completely Automated

Using periodically to reduce solids buildup on membrane surface

Relieves solids tension on membrane surface so they are scoured away

Filtrate pumps are stopped

Jet with mixed liquor and air remains in operation
Maintenance Clean

Completely Automated
Every 1-2 weeks on larger plants
30-40 minutes duration
Inject chlorinated filtrate (200 mg/l) into membrane
Inhibits biological surface fouling
Mixed liquor remains in tank
Clean-In-Place (CIP)
Automated – no membrane removal
Every 2-6 Months
4-6 hours per membrane cell
Mixed liquor sent back to biological tanks
Utilizes chlorine @ approximately 1,000 mg/l
Occasional acid cleans for inorganic fouling
Normal Operation

In-Tank CIP Clean

Mixed Liquor → Air

Jet → Chlorine

Air → CIP

4 - 6 hours

PvDF Oxidant-Resistant Fibers

Jet → Air
Effect of CIP Frequency

Pressure available for unplanned storm events

Terminal TMP
Piloting
5,760 GPD MBR Pilot

- Prescreen
- Anoxic
- Blower
- Aerobic

CIP
Membrane Operating System (MOS)
Complete “Rack” Assembly
MBR Demonstration Plant
Kansas City, Kansas MUD
Plant Design

Design capacity 50,000 GPD

Complete plant includes

- Fine Screen
- Anaerobic Reactor
- Two-stage Anoxic Reactor
- Aerobic Reactor
- Membrane Operating System (MOS)
- Aerobic Digester

Industrially designed for flows up to 20,000 GPD.
Plant Schematic

- Membrane Tank
- Filtrate Tank (also used in CIP & backwash)

Wastewater from pump station

Fine screen

- Fine screen
- Two-stage Anoxic Zone
- Anaerobic Zone
- Aerobic Digester
- Aerobic Zone

Biological Process Air

Mixed Liquor return

Outdoors

- Mixed Liquor return
- Outdoors
Biological Process Tanks
Thank you for your concern.
For questions:
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