PALL Water Processing

Advanced Filtration Technologies
MEMBRANES

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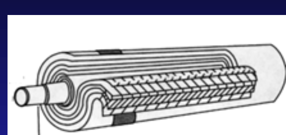
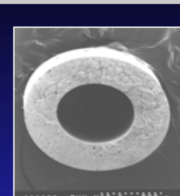
Filtration. Separation. Solution. SM

What is a Membrane Filter?



Membrane Filter



A filter which removes solids entirely at its surface, rather than trapping them within the depth of the medium.

Opposite is a depth filter, e.g. conventional filter.

Roles of Membranes in Treatment

- Remove Pathogens/Disinfection
- Remove Suspended Solids
- Remove Organics
- Remove Inorganics
  - Desalination
  - Softening
  - Iron, Manganese
  - Arsenic
- Water Reuse

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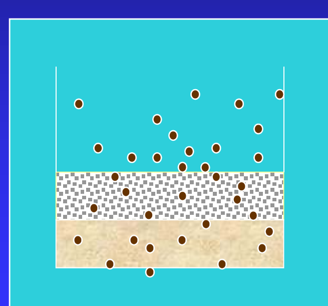
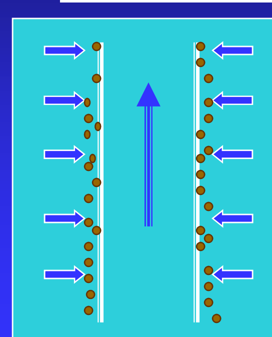
Depth vs. Membrane Filters

- ***Granular / Mixed Media***
  - **Irregular Pore Size**
  - (50 -70 micron media pores)
  - **Probable Filtration**
- ***Membrane Media***
  - **Controlled Pore Size Distribution**

    (sub - micron)
  - **Absolute Filtration**





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Microns

A Micron (µm) Is:

- Also known as a "micrometer"
- One millionth of a meter
- One thousandth of a millimeter
- 39 millionths of an inch (0.000039 in)

Will also see units of Daltons, or
Molecular Weight Cutoff (MWCO)

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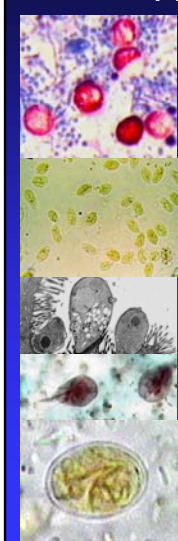
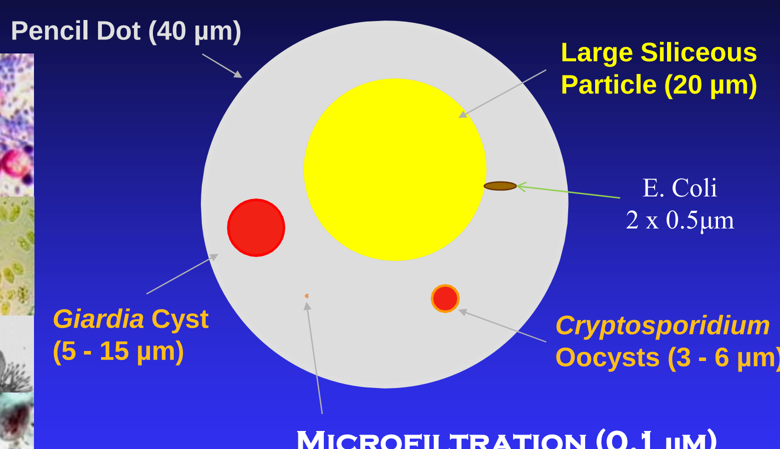
Relative Sizes of Small Particles





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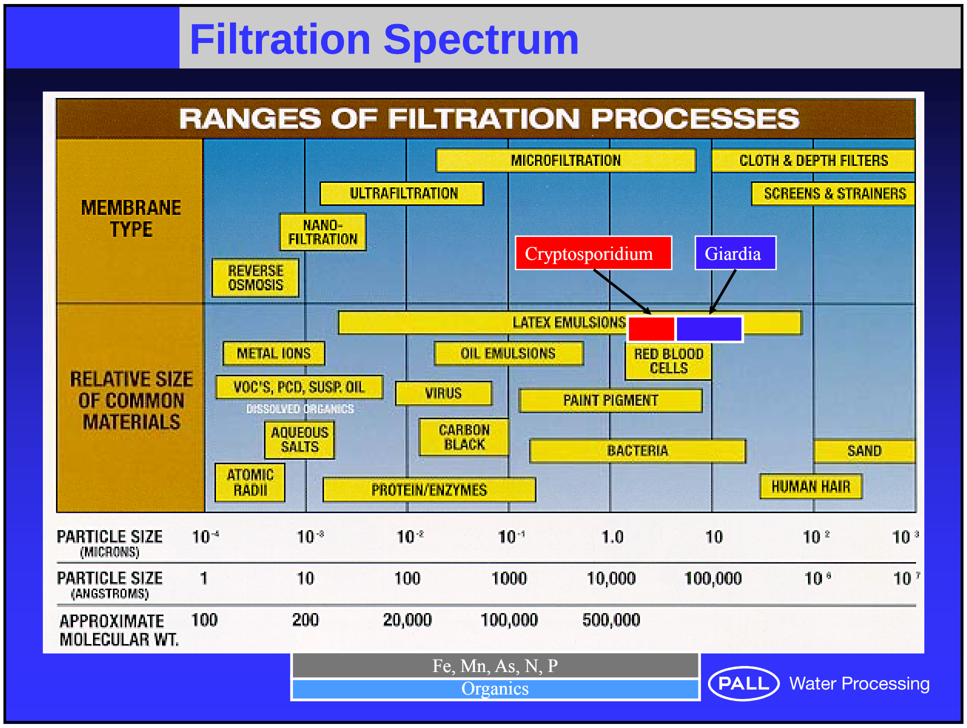
Filtration Spectrum
RANGES OF FILTRATION PROCESSES
MEMBRANE TYPE
MICROFILTRATION
CLOTH & DEPTH FILTERS
ULTRAFILTRATION
SCREENS & STRAINERS
NANO-FILTRATION
Cryptosporidium
Giardia
REVERSE OSMOSIS
RELATIVE SIZE OF COMMON MATERIALS
LATEX EMULSIONS
METAL IONS
OIL EMULSIONS
RED BLOOD CELLS
VOC'S, PCD, SUSP. OIL
DISSOLVED ORGANICS
VIRUS
PAINT PIGMENT
AQUEOUS SALTS
CARBON BLACK
BACTERIA
SAND
ATOMIC RADII
PROTEIN/ENZYMES
HUMAN HAIR
PARTICLE SIZE (MICRONS) 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1.0 10 10^{2} 10^{3}
PARTICLE SIZE (ANGSTROMS) 1 10 100 1000 10,000 100,000 10^{6} 10^{7}
APPROXIMATE MOLECULAR WT. 100 200 20,000 100,000 500,000
Fe, Mn, As, N, P
Organics
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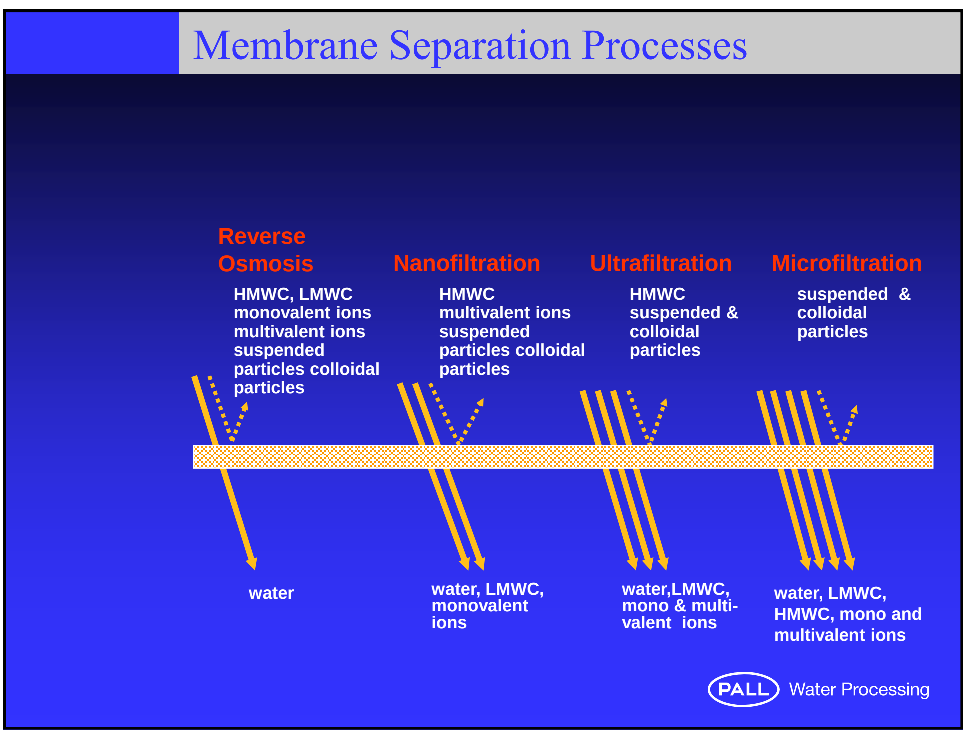
Membrane Separation Processes
Reverse Osmosis
HMWC, LMWC monovalent ions multivalent ions suspended particles colloidal particles
Nanofiltration
HMWC multivalent ions suspended particles colloidal particles
Ultrafiltration
HMWC suspended & colloidal particles
Microfiltration
suspended & colloidal particles
water
water, LMWC, monovalent ions
water,LMWC, mono & multi-valent ions
water, LMWC, HMWC, mono and multivalent ions
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Similarities in Membranes

Membrane Systems

- Modular in design.
  - Membranes housed in removable modules.
- Designed for independent operation.
- Produce consistent finished water quality.
- **Typically require smaller footprint vs. conventional plant.**
- Require knowledge of source water and treatment objectives

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Differences in Membranes

Microfiltration / Ultrafiltration

- Used to remove suspended solids, not dissolved solids.
- Operates at lower pressures (up to 40 pounds).
- Few major suppliers.

Nanofiltration / Reverse Osmosis

- Used to remove dissolved solids, not suspended solids.
- Operates at higher pressures (up to 1,200 pounds).
- Many possible suppliers.

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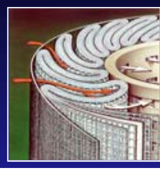
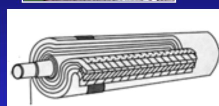
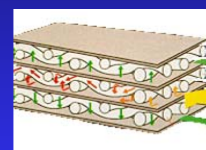
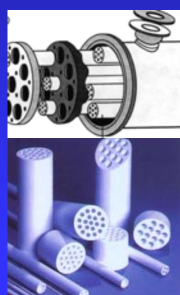
Module Configuration

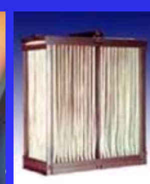
- Flat Sheet
  - Pleated
  - Plate & Frame
  - Spiral Wound
  - Cassette

- Tubular and Ceramic



- Hollow Fiber

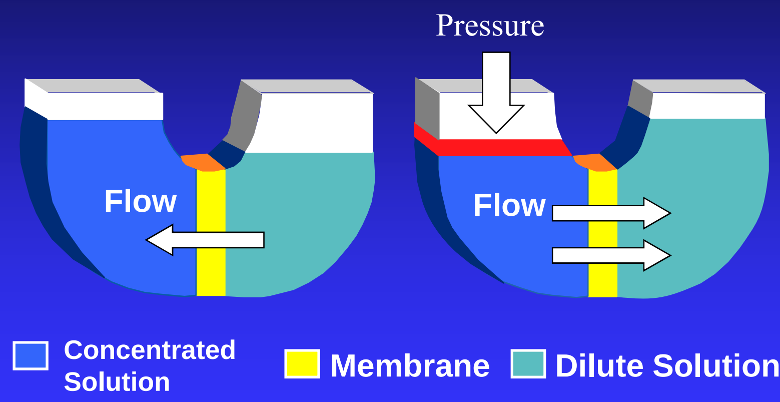



RO / NF Treatment Goals

- Reduce Total Dissolved Solids or Soften Water
  - –Secondary Effluent
  - –Treated Industrial Wastewater (water reuse)
  - –Well Water / Brackish / High Brackish Water
  - –Sea Water
- Reduce Total Organic Carbon
  - Boiler Feed Water
  - High Purity Water (pharmaceutical, electronics)


What is Reverse Osmosis?

Osmosis | Reverse Osmosis



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Typical Operating Pressures

Membrane Process	Pressure Range (psi)
Reverse Osmosis	
seawater	800-1200
brackish water	150-600
Nanofiltration	50-225
Microfiltration	vacuum-45

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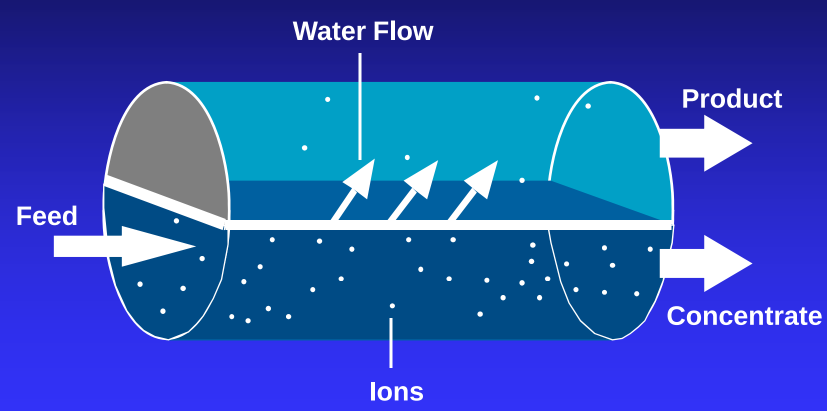
RO / NF Membrane Systems



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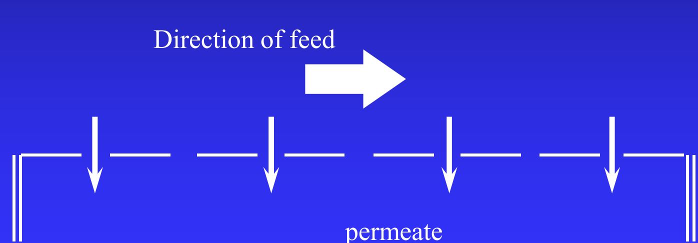
Cross-Flow Filtration

Cross-Flow Filtration

- Results in a concentrate stream as well as permeate stream.
- Sweeps away concentrated salts and foulants.
- Required for reverse osmosis, also used to some extent in other membrane processes.



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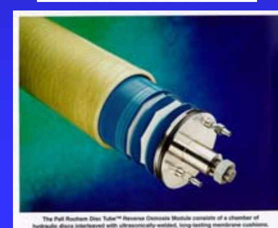
RO / NF Membrane Systems

Types of Modules:

- •Cassettes
  - •Flat sheet in rigid packing
  - •Mostly small scale

- •Plate and Frame (Disc-Tube)
  - •Membrane "sandwiches" or "pillows"
  - •Used in extreme applications
    - •Landfill leachate
    - •Shipboard systems

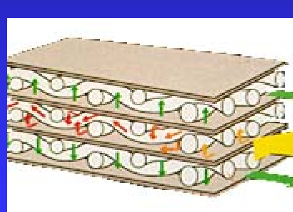


- •Spiral-Wound

RO / NF Spiral Wound Modules

- •Most water applications use spiral wound modules
- •MANY different suppliers of modules!
  - •Dow Filmtec, Fluid Systems, GE Osmonics, Toray, etc.

- •Flat membrane sheet, spacer layer, impermeable layer, all rolled up into a cylinder.



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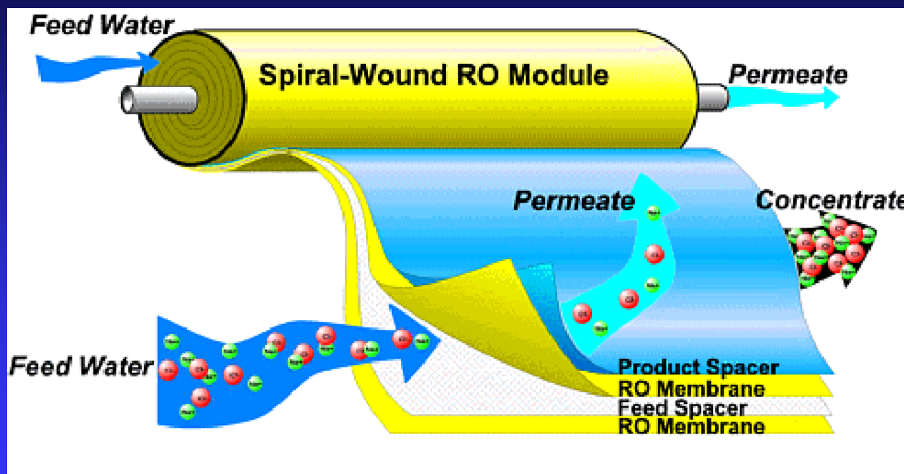
RO / NF Spiral Wound Modules



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RO System Design –Feed Water

For reliable system design, feed water must be reviewed to determine the nature of pretreatment and RO system flux rates.

Critical parameters to be reviewed are:

- Feed water colloids
- BOD/COD, bacteria count, TOC etc.
- Level of hardness, Silica etc
- Oil and grease
- Total Dissolved Solids
- Possible and expected fluctuations in Feed Water quality.

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RO System Design –Requirements

System Requirements review will determine:

- Wastewater disposal costs
- Target finished water quality
- Power costs
- Footprint, labor costs, etc.

System design can be optimized based on the specific requirements.

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RO System Design –Features

Typical Design features

- Multistage RO based on recovery
- Multi-Pass RO based on product water quality

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RO System Design –Pretreatment

Pretreatment requirements are based on the feed water's potential for Fouling or Scaling.

TYPE OF PROBLEM	PT ALTERNATIVES
Bio-Fouling	Chlorination, Filtration etc
Particulate Fouling	Filtration
Hardness related scaling	Softening, pH adjustment, Antiscalents
Others	Case by case review

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RO System Design –Other Issues

Finished water from an RO system may be very aggressive.

- •Blend
- •Limestone bed

RO membranes can trap particles and microorganisms, which may be difficult to remove.

- •Cartridge Filters
- •Microfiltration

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RO System Design –Summary

- RO systems can produce the quality and quantity of water desired.
- Proper and adequate design guidelines should be followed to ensure trouble free operation.
- Best known technology to reduce total dissolved solids cost effectively.

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RO / NF Membrane Systems - Pictures

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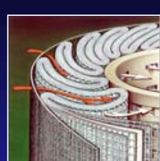
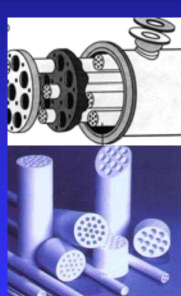
MF/UF Treatment has One Goal

Remove Particulates

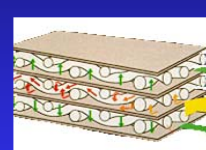
- *Microbiologicals -- Cryptosporidium, Giardia, Animal Parasites, Bacteria, Virus*
- *Remove In-organics -- Fe, Mn, As with proper chemistry*
- *Remove/Reduce Organics -- TOC, NOM (Natural Organic Matter), Color, Taste & Odor, with proper chemistry*
- *Pre-treatment for RO -- SDI < 2 (Pre-RO)*
- *Reduce Turbidity*



MF/UF Types of Modules

- Flat Sheet
  - Pleated
  - Plate & Frame
  - Cassette
- Tubular and Ceramic
- Hollow Fiber

Membrane Materials

- Cellulose Acetate, CA
- Polyacrylonitrile, PAN
- Regenerated Cellulose, RC
- Polyamide, PA
- Polypropylene, PP
- Polyvinylidenefluoride, PVDF
- Polyether sulfone, PS or PES

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MF/UF Suppliers

Relatively few suppliers, but very different technologies.

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Hollow-Fibers are most Common

- Very large surface area in small container.
- Surfaces easy to clean.
- Fibers can be manufactured with consistent pore size and porosity.
- Can be configured in a number of ways for different applications.
  - Pressure vs. Submerged
  - Packing Density
  - Outside-In vs. Inside-Out (Dead-End vs. Cross-flow)

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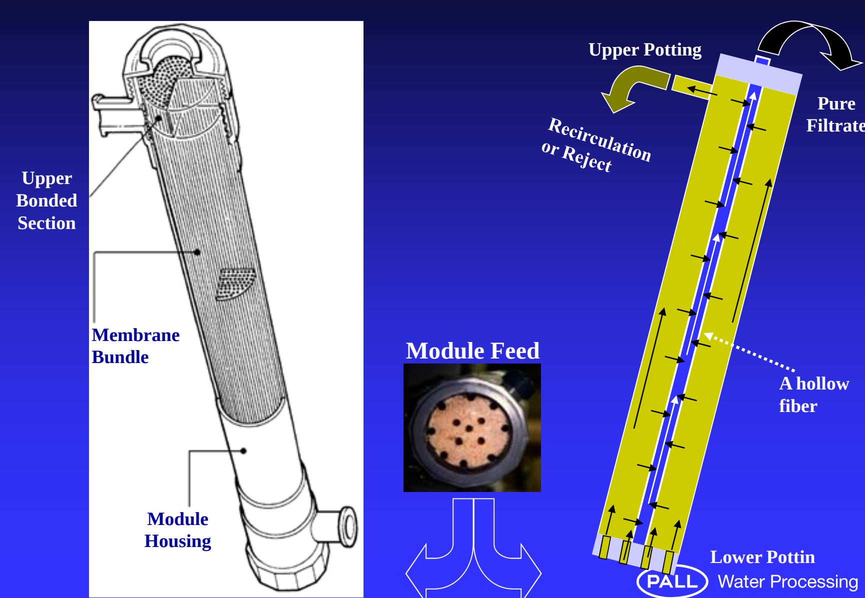
Membrane Module



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Submerged Hollow Fiber Modules

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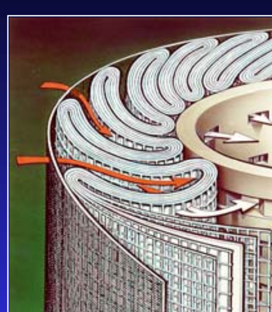
MF - Pleated Filter – Septra CB



- Removal Rating: 1 micron
- Membrane Material: PES
- Flow: Outside - In
- Oxidant Resistant
- Usages: clean GWUI, final Barrier after Conventional plant

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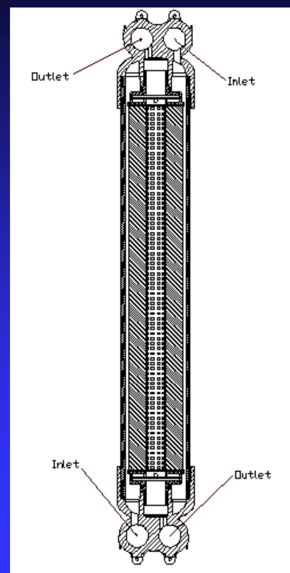
Septra CB Filter Module



Flow Pattern:
Outside-In

Disposable
&
Backwashable

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MF/UF is Physical Process

- Particles are removed because they do not fit through pores on the membrane.
- More pores, higher throughput.
- Solids fill up pores until cleaned off.
- Pressure drop over the membrane indicates how many pores have filled up.

PALL Water Processing

MF/UF is Physical Process

- Particles are removed because they do not fit through pores on the membrane. **(Removal Rating)**
- More pores, higher throughput. **(Flux)**
- Solids fill up pores **(Fouling, Blinding)** until cleaned off. **(Backwash, Clean-in-Place cleaning)**
- Pressure drop over the membrane indicates how many pores have filled up. **(Transmembrane Pressure, or TMP)**

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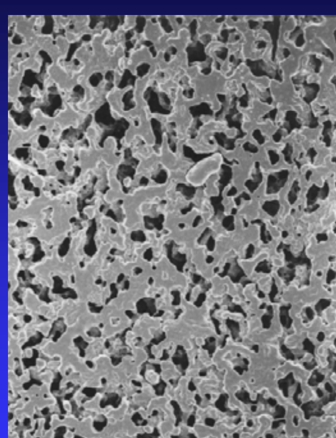
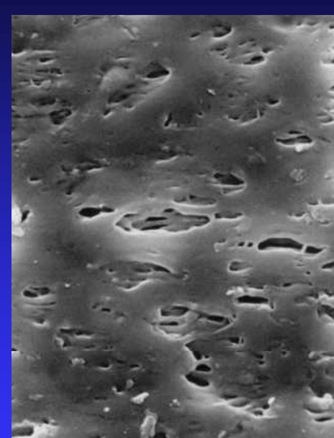
MF - Porosity

Generally, MF membranes are 50 - 90% open space.



Pall Fiber Outer Surface



Brand X Fiber Outer Surface

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Definitions of Removal Ratings

Absolute Rating

The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. This is an indication of the largest opening in the filter medium.

Nominal Rating

A value indicating a particulate size range which the ***filter manufacturer*** claims the filter removes *a* ***certain*** percentage of.

Nominal ratings vary from manufacturer to manufacturer and should not be used to compare filters.

Molecular Weight Cut Off (MWCO)

Nominal rating system for ultrafiltration and nanofiltration membranes. MWCO is defined as the molecular weight of solute that the membrane can retain 90% of.

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Microfiltration vs. Ultrafiltration

Due to a lack of any industry standards or common definitions, these terms should not be used to compare products from different manufacturers!

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Microfiltration vs. Ultrafiltration

Typical Summary of Removals

Microbe	Typical Microfiltration	Typical Ultrafiltration
Giardia Cysts	4.5-7 log	5-7 log
Cryptosporidium	4.5-7 log	5-7 log
MS-2 Bateriophage Virus	**0.5-3.0 log**	**4.5-6 log**
Particle Counts		
>2 micron	<10/ml	<10/ml
2-5 micron	<10/ml	<10/ml
5-15 micron	<1/ml	<1/ml
Turbidity - Average	0.03-0.05 ntu	0.03-0.08 ntu

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MF – Boring Definitions

Flux -- The amount of solution that passes through a unit of membrane area in a given amount of time. For instance, a filter might have a flux of 75 gallons per square foot per day (GFD) of surface area.

Fouling – Plugging of the membrane, decreasing flux. Often requires chemical cleaning of the membrane.

Backwash -- Reversing the flow of fluid through a filter in order to remove trapped solids.

Blinding -- The reduction or cut off of flow due to particles filling the pores of a filter.

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MF – More Boring Definitions

Transmembrane Pressure (TMP) -- The force which drives liquid flow through a cross-flow membrane. The upstream side (the side of the membrane the solution enters by) of a TFF system is under a higher pressure than the downstream side. This pressure difference forces liquid through the membrane.

Differential Pressure (DP) -- is the difference between the pressure in the system before the fluid reaches the filter (upstream pressure) and the system pressure after the fluid flows through the filter (downstream pressure). As the filter begins to clog, differential pressure increases.

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MF - Traditional CIP Practices

- Full vigorous CIP removes all foulants and completely restores permeability
- CIP target interval is 21-30 days
- CIP interval is selected based on a pragmatic balance between several factors:
  a. cost of chemicals
  b. downtime
  c. labor or manpower
  d. membrane longevity

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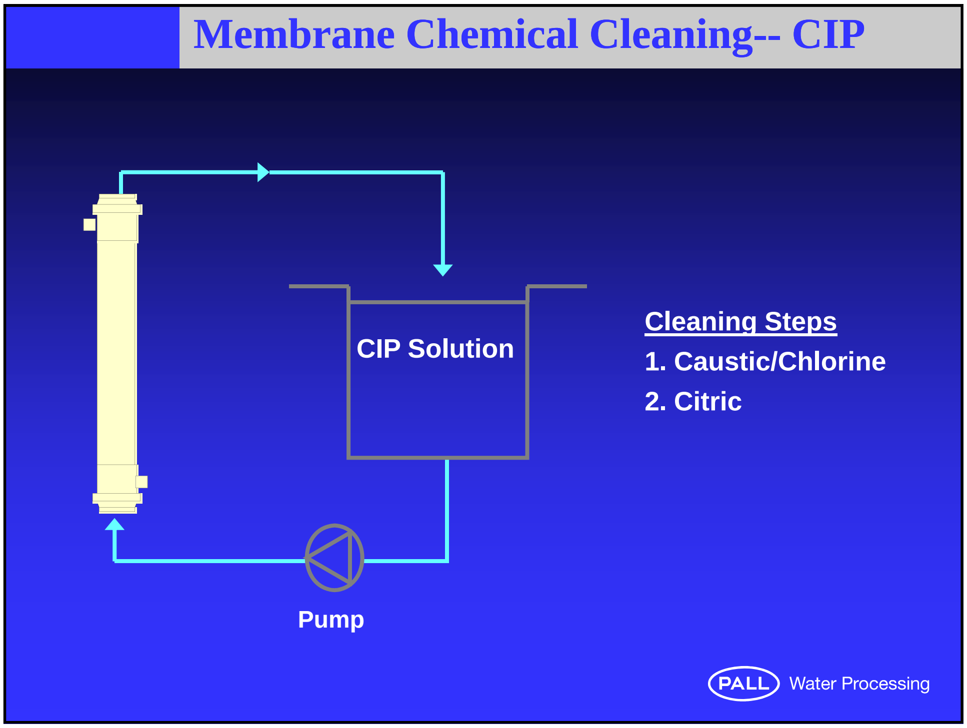
Membrane Chemical Cleaning-- CIP
CIP Solution
Pump
Cleaning Steps
1. Caustic/Chlorine
2. Citric
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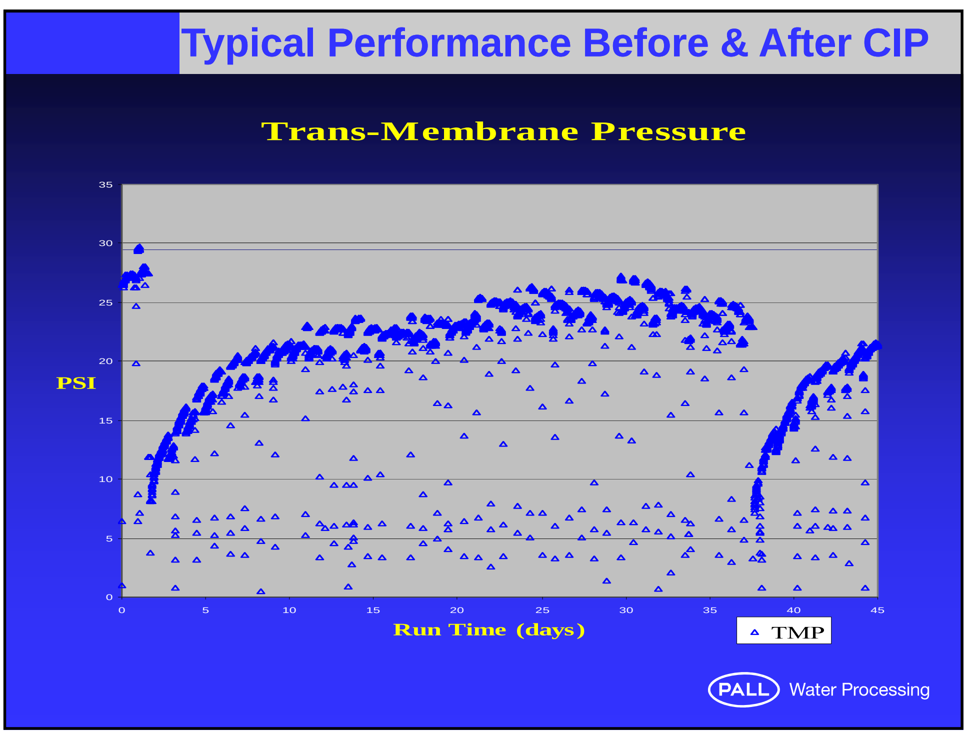
Typical Performance Before & After CIP
Trans-Membrane Pressure
PSI
Run Time (days)
TMP
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MF System Design –Feed Water

For reliable system design, feed water must be reviewed to determine the nature of pretreatment (if any) and their impact on MF system flux rates.

Critical parameters to be reviewed are:

- BOD/COD, bacteria count, TOC etc.
- Presence of metals.
- Total Suspended Solids.
- Possible and expected fluctuations in Feed Water quality.
- Utility of existing equipment.

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MF System Design –Requirements

System Requirements review will determine:

- Wastewater disposal costs
- Desired pretreatment, if any
- Power costs
- Footprint, labor costs, etc.

System design can be optimized based on the specific requirements.

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San Patricio MWD – 8 MGD System

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Chandler, AZ - 1.75 mgd

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Stoney Creek, VA – 250 gpm

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Microfiltration –Summary

- MF systems can produce consistent water quality and quantity of water desired.
- Proper and adequate design guidelines should be followed to ensure trouble free operation.

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Conclusions

- A well-designed membrane system can remove contaminants from a wide variety of source waters.

- Membranes can provide an economical method of meeting water treatment regulations.

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