Intro to Membrane and Fluoridation Technologies

MCET
environmental, health, and safety training

CSM college of southern maryland
La Plata · Leonardtown · Prince Frederick · Waldorf

Fluoridation

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Fluoride is an Ion naturally found in nature.

- Small amounts of fluoride is essential in a diet for proper tooth and bone formation.
- Discovered through comparisons of the teeth of children from areas that have different concentrations of natural fluoride in their drinking water.

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Fluoride Endorsements...

- American Dental Association.
- American Water Works Association.
- Public health groups worldwide.

What determines proper dosage?

- Varies across the country due to average annual air temperature.

3

Each individual State Health Department uses this information to establish optimal fluoride levels.

Annual Average of Maximum Daily Air Temperature,* °F	(°C)	Recommended Control Limits of Fluoride Concentration, mg/L Lower	Optimal	Upper
53.7 and below	(12.0 and below)	0.9	1.2	1.7
53.8–58.3	(12.1–14.6)	0.8	1.1	1.5
58.4–63.8	(14.7–17.6)	0.8	1.0	1.3
63.9–70.6	(17.7–21.4)	0.7	0.9	1.2
70.7–79.2	(21.5–26.2)	0.7	0.8	1.0
79.3–90.5	(26.3–32.5)	0.6	0.7	0.8

Secondary MCL – 2.0 mg/l – causes dental fluorosis
Primary MCL – 4.0 mg/l – causes skeletal fluorosis

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Overfeed!!!
Fluorosis occurs.

- Minor cases - Whitish areas called mottling.
- Severe cases - Causes teeth to darken to shades of gray and black.
- Serious cases - Cause pitting and makes teeth susceptible to cavities and wear.

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Fluoridation Chemicals...

Sodium Fluoride.
(NaF)

- ❑First chemical to be used in fluoridation at water treatment facilities.
- ❑It is a white, odorless material that comes as fines or coarse crystals.

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Fluoridation Chemicals...

Fluorosilicic Acid
(H_2SiF_6)

- It is a clear, colorless to straw yellow colored, fuming and is very corrosive.
- Has a pungent odor, cause skin irritation
- Has a low pH from 1.0 to 1.5.

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Fluoridation Chemicals...

Sodium Fluorosilicate
(Na_2SiF_6)

- Powder or fine crystal
- White or yellowish - white in color.
- Low solubility in water.
- Most inexpensive chemical for fluoridation.

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Item	Sodium Fluoride, NaF	Sodium Fluorosilicate, Na_2SiF_6	Fluorosilicic Acid, H_2SiF_6
Form	Powder or crystal	Powder or very fine crystal	Liquid
Molecular weight	42.00	118.1	144.08
Commercial purity, %	97–98	98–99	20–30
Fluoride ion, % (100% pure material)	42.25	60.7	79.2
Pounds required per mil gal for 1.0 ppm F at indicated purity	18.8, 98%	14.0, 98.5%	35.2, 30%
pH of saturated solution	7.0	3.5–4.0	1.2 (1% solution)
Sodium ion contributed at 1.0 ppm F, ppm	1.17	0.40	0.00
F ion storage space, ft^3/100 lb	22–34	23–30	54–73
Solubility at 77°F, g/100 mL water	4.0	0.762	Infinite
Weight, lb/ft^3	65–90	85–95	10.5 lb/gal, 30%
Shipping containers	100-lb bags, 125–400-lb fiber drums, bulk	100-lb bags, 125–400-lb fiber drums, bulk	13-gal carboys, 55-gal drums, bulk

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Chemical feed systems….

Two ways to feed fluoride
into the water system.

- Dry feed system.
  - Volumetric.
  - Gravimetric.
- Solution feed system.
  - Metering Pump
  - Sodium Fluoride solution from a saturator.
  - Commercially prepared Fluorosilicic Acid from a tank or drum.

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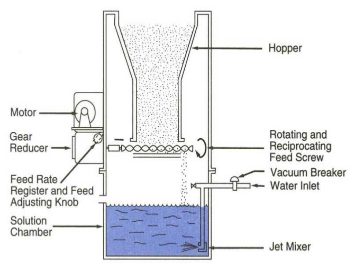
Volumetric Feeders:

- Delivers a set volume of chemical with each revolution of a screw.
- Varying the speed of the screw varies the feed rate.
- Less expensive.
- Less accurate.



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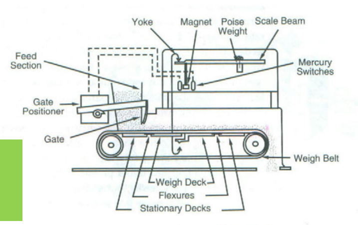
Gravimetric Feeders:

- Delivers a certain weight of chemical for each revolution of a conveyor belt.
- Feeds a predetermined weight.
- Very accurate.
- More expensive.



Both types of dry feeders discharge into a solution tank. Tanks must have a mixer to properly dissolve the chemical.

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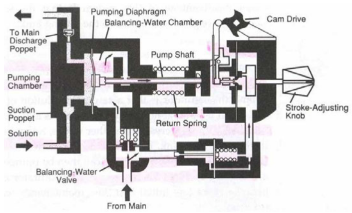
Diaphragm or Piston Pumps…

- Feed a constant rate at a constant speed.
- Controlled by flow rate or manually set.



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Saturators…

- Upflow Saturators.
- Downflow Saturators.
- Eliminates constant chemical handling.
- Great for small systems.

- **Water is allowed to trickle through a layer of Sodium Fluoride, forming a solution of constant concentration which is fed into the water system.**

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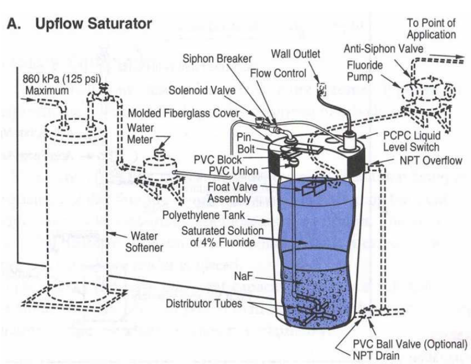

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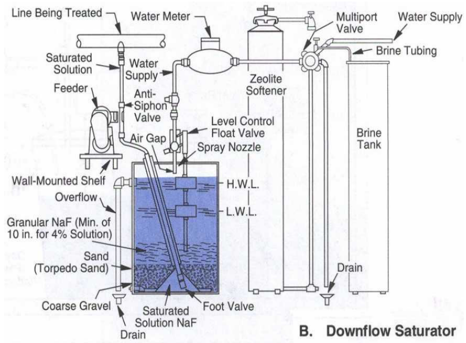

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Saturators...

- Saturators create a fluoride solution of 4% NaF or 1.73% Fluoride ion. This known concentration can be fed to a water supply by a chemical feed pump.
- There must be at least 6 inches of chemical in the saturator at all times. 10 inches for higher flow systems.

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Acid Feed Systems...

- Simplest installation.
- Fed right from the shipping container.
- Larger Systems - Truck loads.
- Small Systems - Carboys.

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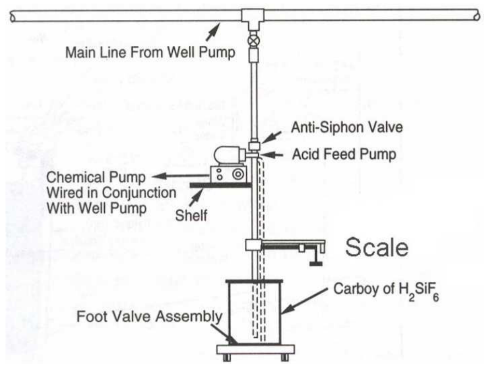

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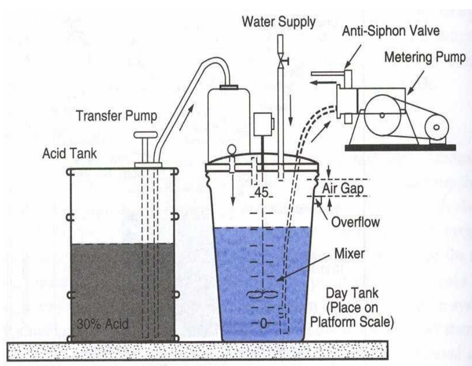

Must have protection against backflow or backsiphonage when a concentrated chemical is connected to a water system

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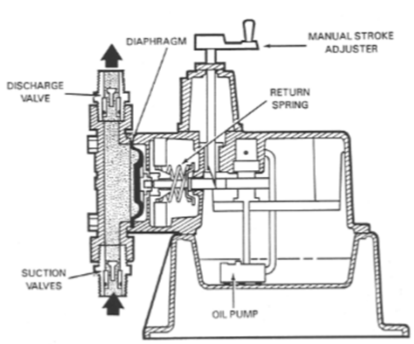
TYPICAL MECHANICAL DIAPHRAGM METERING PUMP



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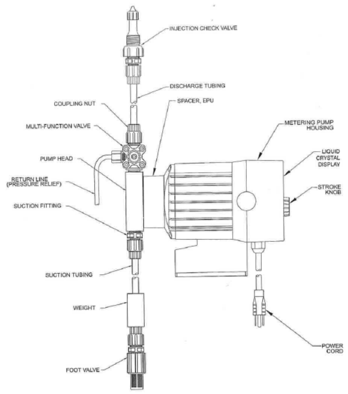

Metering Pump Component Diagram

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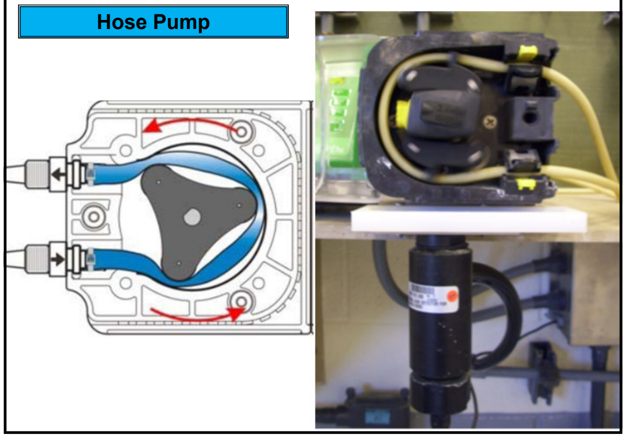
Hose Pump



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How often should fluoride concentrations in the drinking water be measured?

- At least once per shift.
- Automatic monitors that continuously read fluoride concentrations and activate an alarm when levels get too high.
- 3 typical lab procedures:
    - SPADNS
    - Alizarin-Visual
    - Specific Ion Probe

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Fluoride Safety.
3 ways of overexposure….

- Ingestion.
- Inhalation.
- Bodily contact.

Fluoride Safety Equipment…

- Goggles.
- Respirator or mask (approved by NIOSH).
- Rubber gloves.
- Rubber aprons.
- Rubber boots.

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1. Why are drinking waters fluoridated?
   Drinking waters are fluoridated to reduce the incidence (number) of dental caries (tooth decay) in children.
2. What factors would you consider when selecting a fluoridation chemical?
   When selecting a fluoridation chemical, you must consider the solubility of the chemical in water, operator safety, ease of handling, storage and feeding requirements, and costs.
3. How can water be softened before use with fluoridation equipment?
   Water can be softened prior to use with fluoridation equipment by the use of zeolite ion exchangers.
4. What items should be considered when reviewing plans and specifications for the location of fluoride chemical hoppers?
   The chemical hoppers should be located where there is plenty of room so they can be conveniently and safely filled with the fluoride chemical.
5. Why is it important for operators to ensure that no overfeeding of fluoridation chemicals occurs? How can overfeeding be prevented?
   Operators must ensure that no overfeeding occurs because no additional benefits result from overfeeding and there is a waste of chemicals and money. Excessive overfeeding could be harmful to consumers. Overfeeding can be prevented by proper operation and continuous monitoring of the product water.

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6. What should be done if significant overfeeding occurs?
   If significant overfeeding occurs, the plant should be shut down. The affected mains should be flushed and the local and state health departments notified.
7. What should be done when fluoridation equipment is going to be shut down for an extended length of time?
   When fluoridation equipment is going to be shut down for an extended length of time, the equipment should be cleaned out to prevent corrosion or the solidifying of the chemical. Lines and equipment could be damaged when restarted if chemicals left in them solidify.
8. How would you dispose of fluoride chemical containers?
   To dispose of fluoride chemical containers, thoroughly rinse them with water to remove all traces of chemicals before allowing the containers to leave the plant. Containers may be burned if a nuisance will not be created. Remember that fluoride fumes can kill vegetation and are harmful to people.
9. How would you protect yourself from the dust of dry fluoride compounds?
   To protect yourself from the dust of dry fluoride compounds, be sure the dust collector system works properly. Even with the use of dust collector systems, dust will circulate in the air. Always use approved respirators equipped with cartridges for organic dusts and vapors, protective coveralls, and gloves when emptying sacks or cleaning up equipment and plant surfaces.

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Fluoride has a primary standard (MCL) of ___ mg/L, and a secondary (SMCL) of ___ mg/L.

a. Primary 1.0 mg/L, secondary 0.7 mg/L

b. Primary 2.0 mg/L, secondary 1.0 mg/L

c. Primary 4.0 mg/L, secondary 2.0 mg/L

d. Primary 5.0 mg/L, secondary 3.0 mg/L

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A fluoride saturator ___.

a. Can only be used by large treatment plants.

b. Eliminates the need for a metering pump.

c. Eliminates the need for chemical handling.

d. Is suitable for small water systems.

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A common symptom of fluorosis is teeth that ___.

a. Darken, turning shades of brown

b. Are mottled in appearance

c. Are less susceptible to cavities and erosion

d. All of the above

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The most severe form of fluorosis is teeth that _____.

a. Show signs of pitting.

b. Darken, turning shades of gray to black.

c. Are mottled in appearance.

d. Are less susceptible to cavities and erosion.

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The SPADNS method can be used to determine the concentration of _____.

a. Coliform bacteria

b. Dissolved oxygen

c. Fluoride

d. Iron

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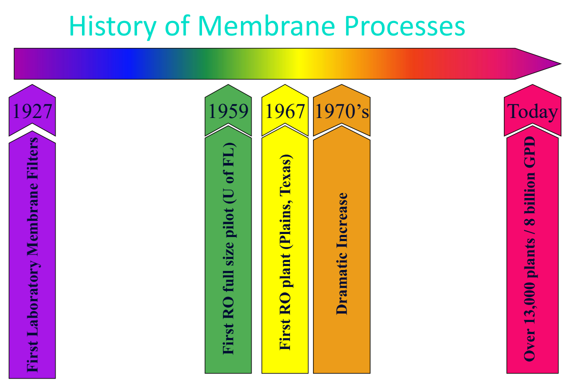

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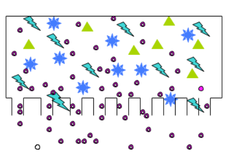
Membrane Filter Technology

- A membrane is a thin material that has pores (holes) of a specific size
- Membranes trap larger particles that won't fit through the pores of the membrane, letting water and other smaller substances through to the other side

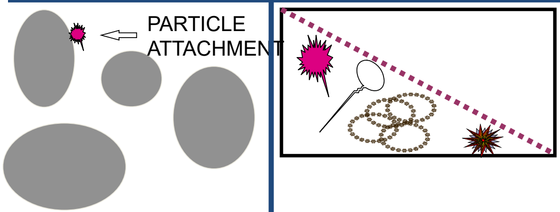


DESPITE VARIATIONS IN CONFIGURATIONS AND TYPES, THEY ARE ALL PRESSURE OR VACUUM DRIVEN EXCEPT EDR WHICH IS ELECTRICAL POTENTIAL DRIVEN

3

COMPARISON TO CONVENTIONAL TREATMENT

CONVENTIONAL FILTRATION | MEMBRANE PROCESS



PROBABILITY OF CAPTURE

99.6% CREDIT

BARRIER BY MECHANICAL RETENTION

99.99% CREDIT

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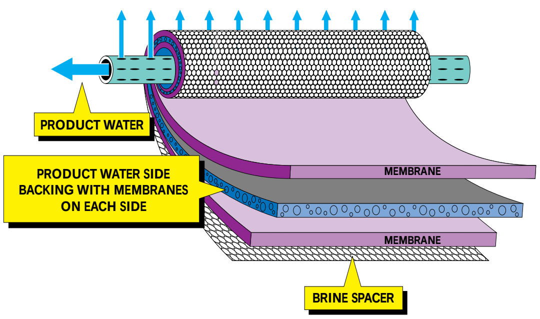
Membrane Filtration



Typically used for demineralization

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WELL BEYOND MUNICIPAL & CONVENTIONAL APPLICATIONS

- TARGETING SPECIFIC CONTAMINANTS (NITRATE, RADIUM, ARSENIC, ETC.)
- INDUSTRIAL RECOVERY/REUSE
- ULTRA PURE WATER
- PHARMACEUTICAL
- FOOD INDUSTRY
- COOLING TOWER/POWER INDUSTRY
- ELECTRONICS & COMPUTER
- LABORATORIES
- …….. MUCH MORE

6

UNIQUE FEATURES OF MEMBRANES

- IT IS A BARRIER
- IT IS MODULAR
- EASY TO OPERATE
- CAN BE MADE ATTRACTIVE

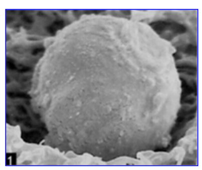
7

CHALLENGE TESTS IN MF & UF PILOT TRIALS HAVE SHOWN SUCCESS BEYOND PENDING REGULATIONS

Giardia Cysts

REG: 3 LOGS

CAPABILITIES: 6-8 LOGS



Cryptosporidium Oocysts

REG: 2 LOGS

CAPABILITIES: 6-8 LOGS

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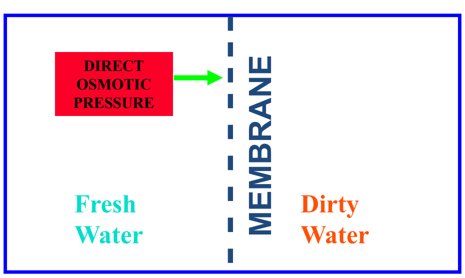
Principle of Osmotic Pressure



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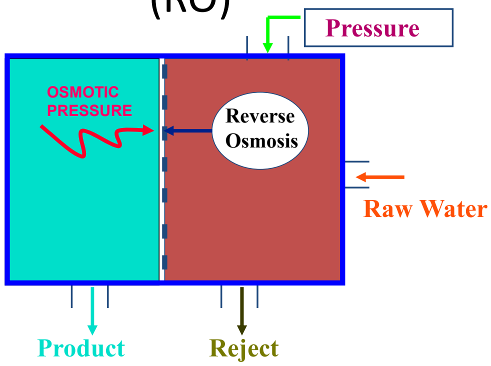
Principle of Reverse Osmosis (RO)



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What makes a Membrane Work

- Pore size - density and distribution
  - ▶ Small pores = Better separation
  - ▶ More pores = Better flow per area (flux)
  - ▶ Close distribution of pore size = Consistent separation
- Manufacturing membranes to a consistent quality standard is difficult – a few large pores can ruin separation performance

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What makes a Membrane Work

- Permeability (flux per unit pressure at set temp)
  - ▶ Flux (flow per unit area)
    - gal/day/sq ft = gfd or liters/ sq m/hr = lmh
    - Higher flux = smaller less expensive plant
  - ▶ Trans-membrane pressure (TMP)
    - Higher delta P = More flow
  - ▶ Temperature
    - Lower temperature = Lower flow (viscosity or diffusion driven)
  - ▶ Water quality – particles, dissolved solids & organic matter
    - More “solids” = Lower flow

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Types of Membrane Processes

Removal of colloids / particles

- Microfiltration
  - Particle (> ~0.1 µm) removal (cyst removal)
- Ultrafiltration
  - Macromolecule & particle removal

Removal of dissolved material

- Nanofiltration (NF)
  - Softening (Ca, Mg); NOM removal
- Reverse Osmosis (RO)
  - Demineralization: membrane passes water and rejects ions and larger size molecules

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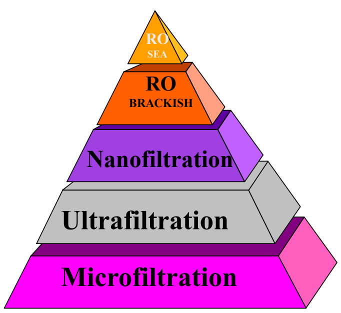
There are five basic membrane systems.



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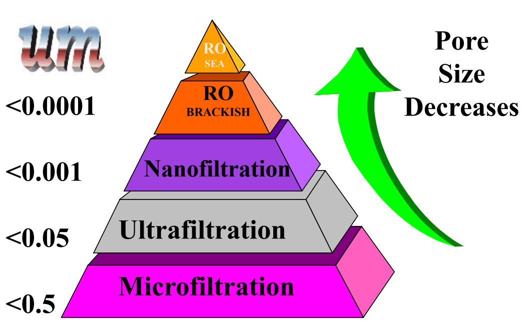
PORE SIZES



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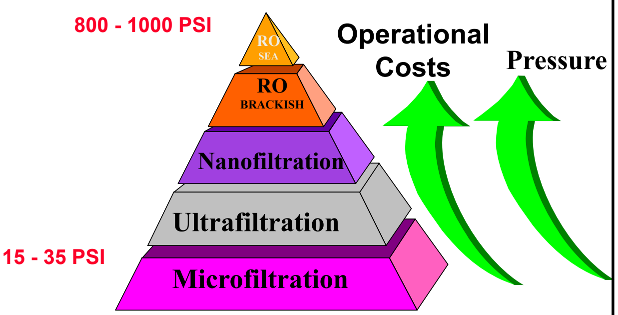
How do they compare?



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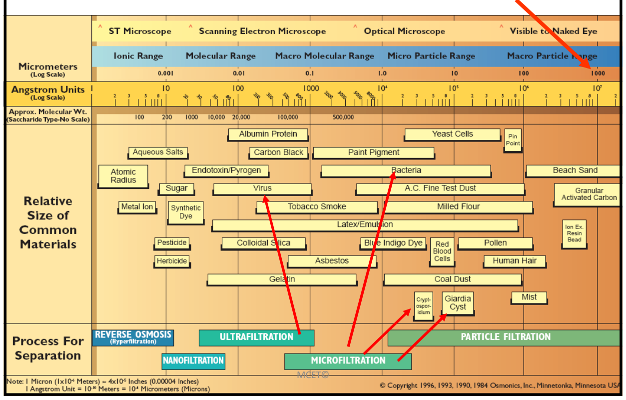
Filtration Spectrum

Log Scale in Microns
(1.0 mm)



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Membrane Filter Technology

Filter type	Symbol	Pore Size, µm	Operating Pressure, psi	Types of Materials Removed
Microfilter	MF	1.0-0.01	<30	Clay, bacteria, large viruses, suspended solids
Ultrafilter	UF	0.01-0.001	20-100	Viruses, proteins, starches, colloids, silica, organics, dye, fat
Nanofilter	NF	0.001-0.0001	50-300	Sugar, pesticides, herbicides, divalent anions
Reverse Osmosis	RO	< 0.0001	225-1,000	Monovalent salts

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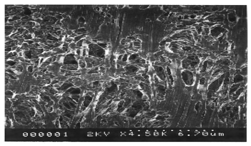
Microfiltration

- Typical pore size: 0.1 microns (10^{-7}m)
- Very low pressure
- Removes bacteria, some large viruses
- Does not filter out:
  - small viruses, protein molecules, sugar, and salts


Microfiltration water plant, Petrolia, PA


A microfilter membrane

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Microfiltration (MF)

MF removes:

- Bacteria, *Giardia*, *Cryptosporidium*
- Turbidity and suspended solids
- Viruses to some degree

MF does not remove:

- Color or organic carbon
- Taste and odor (T&O) compounds
- Dissolved salts

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Ultrafiltration

- Typical pore size: 0.01 microns (10^{-8}m)
- Moderately low pressure
- Removes viruses, protein, and other organic molecules
- Does not filter out ionic particles like:
  - lead, iron, chloride ions; nitrates, nitrites; other charged particles


An ultrafiltration plant in Jachenhausen, Germany

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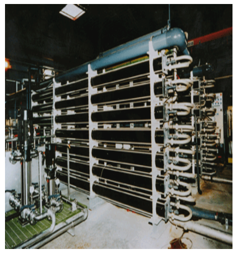
Nanofiltration

- Typical pore size: 0.001 micron (10^{-9}m)
- Moderate pressure
- Removes toxic or unwanted bivalent ions (ions with 2 or more charges), such as
  - Lead
  - Iron
  - Nickel
  - Mercury (II)



Nanofiltration water cleaning serving Mery-sur-Oise, a suburb of Paris, France

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Microfiltration (MF) and ultrafiltration (UF)

Used in water treatment for:

- Particle
- Sediment
- Algae
- Bacteria
- Virus removal as well as
- *Giardia* and *Cryptosporidium.*

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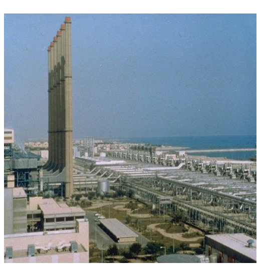
Reverse Osmosis (RO)

- Typical pore size: 0.0001 micron (10^{-10}m)
- Very high pressure
- Only economically feasible large scale method to remove salt from water
  - Salty water cannot support life
  - People can't drink it and plants can't use it to grow



Reverse osmosis (or desalination) water treatment plants, like this one, are often located close to the ocean

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Reverse osmosis (RO) and nanofiltration (NF)

Are used to remove:

- Dissolved organic matter
- Dissolved contaminants (arsenic, nitrate, pesticides, and radionuclides).
- Remove ions (calcium, magnesium, sodium).

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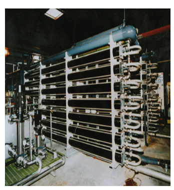
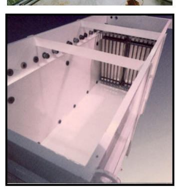
Typical water treatment membrane filtration units

Are installed:

- ❑ **Either in pressure vessels**
- ❑ **Or submerged in tanks.**





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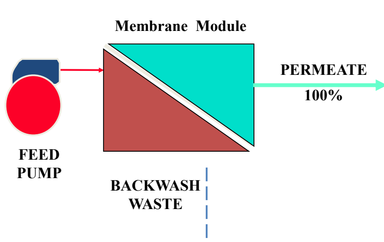
TWO DIFFERENT MODES OF OPERATION

DEAD END WITH FREQUENT BACKWASH



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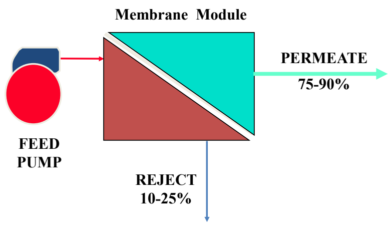
TWO DIFFERENT MODES OF OPERATION

CONTINUOS CROSS FLOW



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Electrodialysis

Basic Unit Components:

- ❑ Pretreatment Equipment
- ❑ Pumping Equip. (feed, brine, recirculation)
- ❑ DC Power Supply
- ❑ Membrane stack and electrodes
- ❑ In-Place cleaning system

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Electrodialysis

Feed Water:

- ❑ Chlorine residual at any concentration
- ❑ Hydrogen Sulfide at any concentration
- ❑ Hexametaphosphates >10 mg/l
- ❑ Manganese in excess of 0.1 mg/l
- ❑ Iron in excess of 0.3 mg/l

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Membrane Filtration Plant

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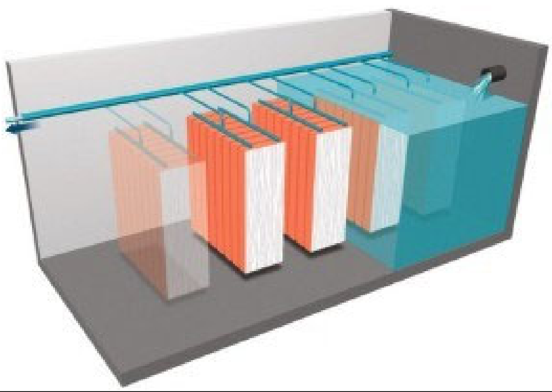
Vacuum Operated Membranes



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Checklist – Membrane Filtration

- ✓ Type of membrane used and intended purpose?
- ✓ Type of pretreatment?
- ✓ Safeguards to warn operators of membrane failure?
- ✓ Fouling rate and life of the membranes?

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Checklist – Membrane Filtration

- ✓ Percent recovery and technique used for backwash?
- ✓ Frequency of cleaning and disposal of cleaning fluids and brines?
- ✓ Condition of the plant, gauges and appurtenances?

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Reverse Osmosis Process

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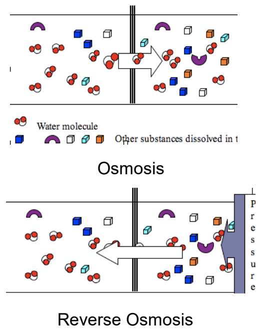
How RO Works

- Osmosis is a natural process that moves water across a semipermeable membrane, from an area of *greater concentration to an area of lesser concentration* until the concentrations are equal
- To move water from a *more concentrated area to a less concentrated area* requires high pressure to push the water in the opposite direction that it flows naturally



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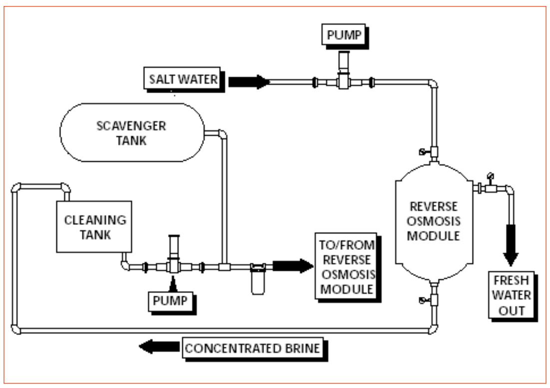
Reverse Osmosis



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Reverse Osmosis Equipment

- Pump
- Membrane
- Acid feed
- Scale inhibitor feed
- Chlorinator
- Cleaning tank, pump, and solution

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Reverse Osmosis– Performance

The primary advantage:

- Rejects a high percentage of dissolved solids from the raw water.
- Allows contaminated, brackish, and saline water to be desalted for potable use.

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Reverse Osmosis– Performance

Problems include:

- High initial and operating costs.
- Need for pre-treatment of turbid raw water by pre-filtration
- Acid and other chemicals to prevent fouling of the membranes by slimes, suspended solids, iron, manganese, and precipitates of calcium carbonate and magnesium hydroxide.
- Need to stabilize finished water with pH adjustment chemicals to prevent corrosion in the distribution system.
- Disposal of reject waste stream can be a problem because of TDS and/or specific contaminants that might occur at hazardous levels (e.g. arsenic or radionuclides).

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Sanitary Deficiencies– Reverse Osmosis

1. Performance testing?
2. Operational data collected?
3. Chemicals fed, and dosages?
4. Are operators protected?
5. Automatic controls operable?
6. Blending ratio (treated and untreated)?

42

Checklist – Reverse Osmosis

- ✓ Performance testing?
- ✓ Operational data collected?
- ✓ Chemicals fed, and dosages?
- ✓ Operators protected (safety)?
- ✓ Automatic controls operable?
- ✓ Blending ratio (treated and untreated)?

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Start-up - Reverse Osmosis

- ✓ Check Cartridge Filters
- ✓ Start-up and check scale inhibitor
- ✓ Start chlorine feed if need to control biological growth
- ✓ Start-up and adjust / set acid feed
- ✓ Start pumps – feed
- ✓ Adjust Permeate and concentrate flow
- ✓ Check pressure differential

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Membrane Filtration Plant

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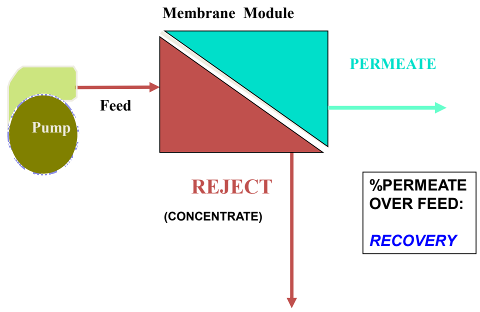
SIMPLIFIED SCHEMATIC



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DEFINITIONS & TERMINOLOGY

RECOVERY: (PERMEATE FLOW / FEED FLOW)*100

FLUX: PERMEATE FLOW / MEMBRANE SURFACE AREA GALLONS PER SQUARE FOOT PER DAY (GFD)

CONCENTRATION POLARIZATION: CONCENTRATION INCREASE AT THE IMMEDIATE SURFACE OF MEMBRANE

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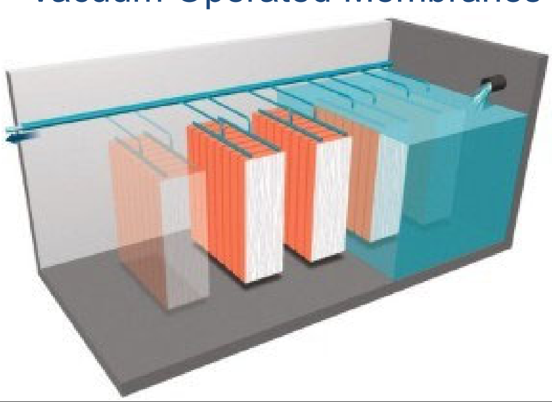
Vacuum Operated Membranes



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MEMBRANE COSTS

TYPE	PRESSURES psi	EQUIPMENT COST $M/MGD	O&M COST $/KGAL	WATER COST* $/KGAL
MF	10- 30	0.5 - 1	0.3 - 0.4	0.4 - 0.6
UF	20- 75	0.5 - 1.1	0.3 - 0.6	0.4 - 0.7
NF	80 - 150	0.8 - 1.2	0.4 - 0.7	0.6 - 0.9
BWRO	200 - 700	0.9 - 1.5	0.8 - 1.5	1.0 - 2.0
SWRO	700 - 1200	2.0 - 6.0	2.0 - 4.0	2.0 - 4.0

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DIFFERENT TYPES OF MATERIAL

MAJORITY MADE FROM ORGANIC POLYMERS

- CA — CELLULOSE ACETATE
- CTA
- PA
- TFC — THIN FILM COMPOSITE
- PS
- PP
- PVDF
- AND MORE !

50

PACKAGED IN DIFFERENT CONFIGURATIONS

- SPIRAL WOUND
  - HOLLOW FIBER
- TUBULAR
- PLATE & FRAME
- CERAMIC & DISCS
- IMMERSED / SUCTION

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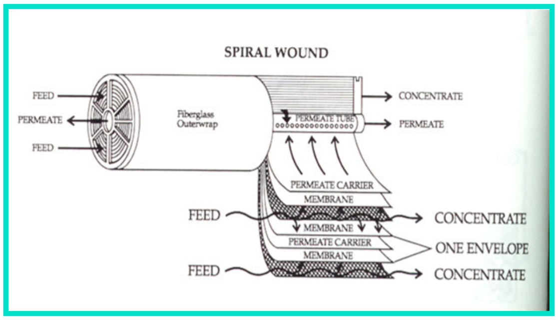
SPIRAL WOUND SYSTEM



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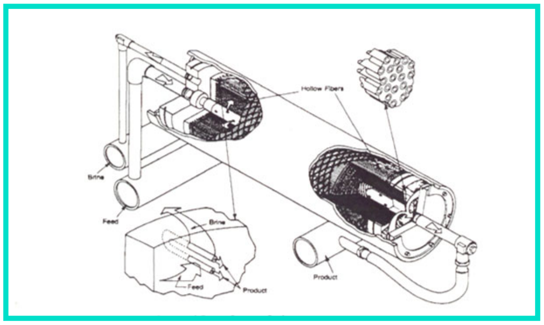
HOLLOW FIBER SYSTEM



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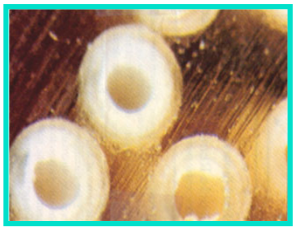
CLOSE - UP VIEW



HOLLOW FIBER

SPIRAL WOUND

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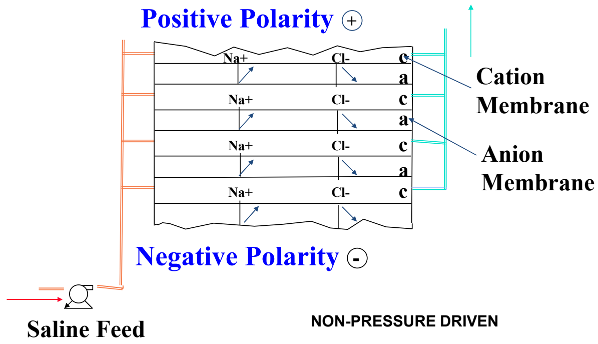
EDR requires ion to be charged & is electrical Potential driven



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SOME EXAMPLES

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EXAMPLES OF LARGE PLANTS

LOCATION	TYPE	MGD
CAPE CORAL, FL	BWRO	15
SARASOTA, FL	EDR	12
SCOTTSDALE	MF	18.5
DEL RIO, TX	UF	28
PITTSBURGH, PA	MF	20
SAN JOSE,CA	MF	6
FORT MYERS, FL	NF	12
BAHRAIN	UF/SWRO	10
TAMPA BAY,FL	SWRO	25
ONTARIO	MF	9.5
NEWPORT NEWS,VA	BWRO	6
CHESAPEAKE,VA	CONV/RO	8

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EVEN SEAWATER IS BECOMING AFFORDABLE

LOCATION	SALINITY	MGD	$M
• TAMPA	26,000	25	94
• TRINIDAD	34,000	28	120
• LARNACEA	35,000	10	40

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OTHER REASONS FOR GROWTH

FRESH WATER SOURCES LONG DISTANCE AWAY

NATIONAL SECURITY/CONFLICTS/INDEPENDENCE

(22 COUNTRIES DEPEND ON OTHERS FOR WATER)

NON-SMART GROWTH
(50% POP. INCREASE IN FL/TX/CA IN NEXT 20 YEARS)

SOMETIMES CHOSEN BECAUSE OF SMALL FOOTPRINT & AESTHETICS

59

CURRITUCK, NORTH CAROLINA

0.2 MGD

EXPAND TO 0.5

NF SOFTENING

W/ CONV TO BW RO

90% RECOVERY

155 PSI

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KILL DEVIL HILL PLANT, NC

3.0 MGD

EXPANDABLE TO 8

FEED TDS: 3,800

3 TRAINS

61

HARLINGEN , TEXAS

4 MGD RO

3 SKIDS

WASTEWATER PURIFICATION FOR INDUSTRIAL SALE

62

CITY OF FREDERICK EMERGENCY UF PLANT

1 MGD CAPACITY
HIGH COLIFORM
HIGH TURBIDITY
LEASE (TEMP. PLANT)
EXTREMELY FAST SCHEDULE

63

JUPITER ISLAND BWRO

2MGD (EXPAND TO 4MGD) BWRO
HIGH H2S
SIGNIFICANT POST TREATMENT
2 STAGE, 80% RECOVERY

64

FORT MYERS, FLORIDA

COURTESY OF BOYLE ENGINEERING

12 MGD

EXPAND TO 20

3-4 MGD SKIDS
NF SOFTENING
90% RECOVERY
155 PSI, W/BWRO
CONVERSION
PLANNED

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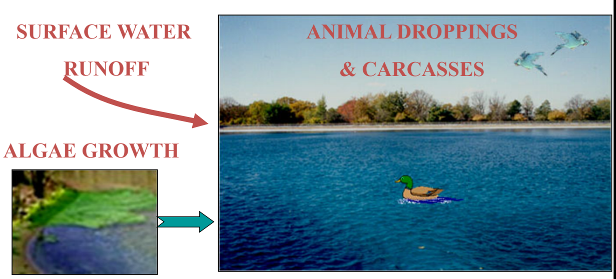
PITTSBURGH

MANDATE "Cover all finished water reservoirs"

- Public Health Issues - Microbial Contamination



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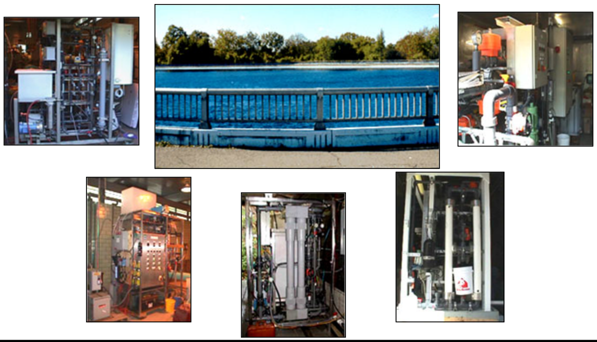
PITTSBURGH 25 MGD POST TREATMENT



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HOLLOW FIBER, 8 RACKS

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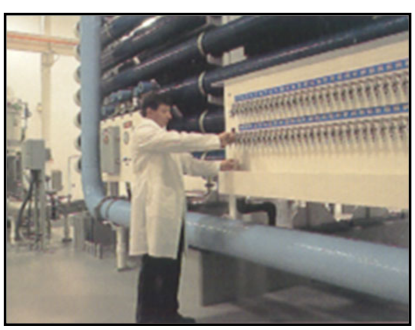
VERO BEACH, FLORIDA



6 MGD

EXPAND TO 10

3-2 MGD SKIDS

LOW PRES. BWRO

85% RECOVERY

175 PSI

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MARCO ISLAND RO

RECENTLY EXPANDED TO 6 MGD

10,000 TDS FEED WATER

COURTESY OF BOYLE ENGINEERING

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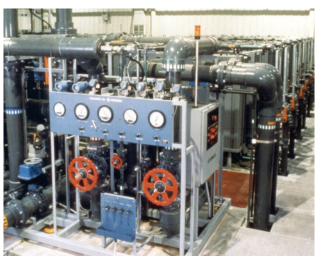
SUFFOLK, VIRGINIA



3.8 MGD
EDR PLANT
TDS REDUCTION &
NATURAL FLUORIDE REMOVAL

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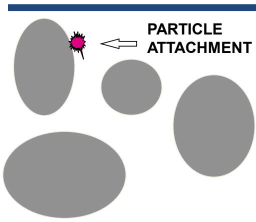
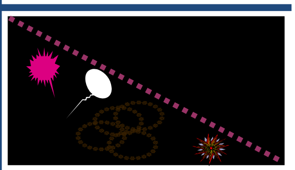
COMPARISON TO CONVENTIONAL TREATMENT

CONVENTIONAL FILTRATION	MEMBRANE PROCESS





PROBABILITY OF CAPTURE

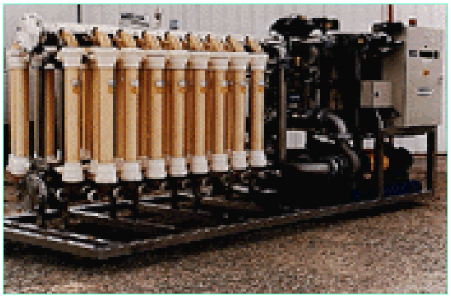
99.6% CREDIT

BARRIER BY MECHANICAL RETENTION

99.99% CREDIT

72

FULLY AUTOMATED PACKAGED PLANTS AVAILABLE



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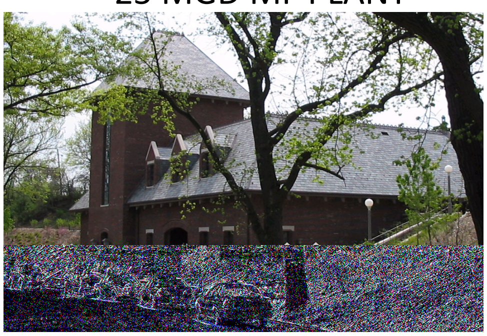
SMALL FOOT PRINT (12,000 SF BLDG) 25 MGD MF PLANT



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CAN BE MADE ATTRACTIVE

10 MGD CAPACITY, VERO BEACH FLORIDA

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OPERATIONAL ISSUES

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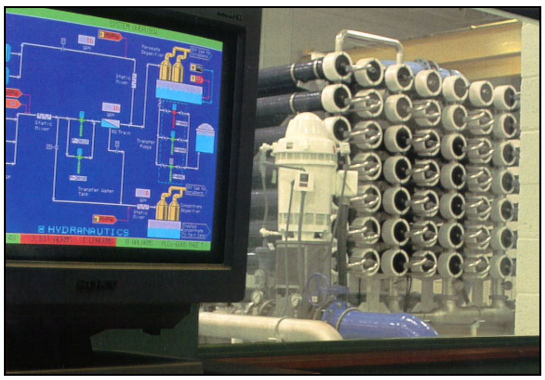
EASY TO OPERATE



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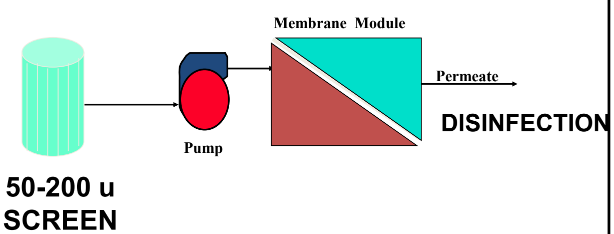
PRE/POST TREATMENT

MF / UF



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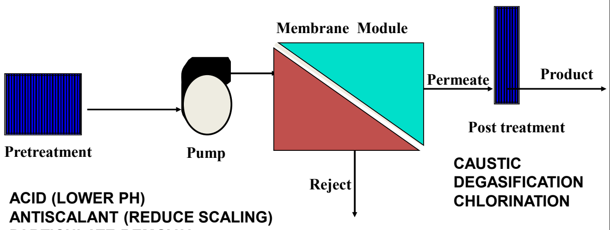
PRE/POST TREATMENT

RO



CAUSTIC
DEGASIFICATION
CHLORINATION

ACID (LOWER PH)
ANTISCALANT (REDUCE SCALING)
PARTICULATE REMOVAL
CARTRIDGE FILTERS

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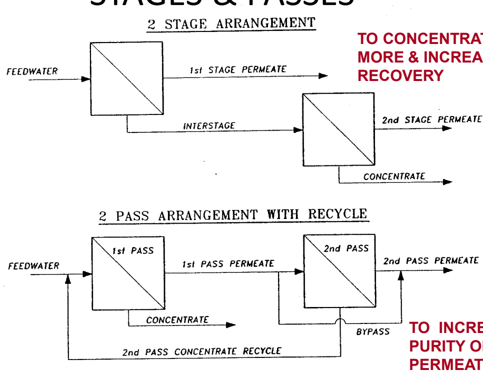
STAGES & PASSES



TO CONCENTRATE MORE & INCREASE RECOVERY

TO INCREASE PURITY OF PERMEATE

80

Backwashing membrane filters

Occurs for three possible conditions:

- Elapsed time since the last backwash
- Total water produced since the last backwash
- Pressure increase since the last backwash.

Backwashing may be by air or by water

81

CAREFUL SELECTION & OPERATION IS CRUCIAL

- Requires detailed evaluation & piloting
- May require pretreatment
- Potential fouling/scaling if not properly selected
- Requires operator training & knowledge

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SCALING CONCERNS

PRECIPITATION OF SUPER SATURATED CARBONATES, SULFATES, SILICATE, ETC. RESULTS IN TMP INCREASE

IN 70's & 80's USED TO BE A BIG PROBLEM. BUT WE NOW CAN PREDICT IT & CONTROL IT.
**ALTERING pH & ADDING SCALE INHIBITORS*
**WELL DESIGNED BRINE SPACERS*
**ADEQUATE FLUSHING VELOCITIES*
**OPTIMIZATION OF HYDRAULICS IN THE SYSTEM*
**EFFECTIVE CLEANING*

83

FOULING CONCERNS

PHYSICAL DEPOSITS (SUCH AS CLAY, SILT, METAL OXIDES, BIOLOGICAL SLIME, ALGAE, ETC.) ON THE SURFACE & INTO MEMBRANE PORES CAUSES INCREASE IN TMP & POOR WATER QUALITY

ORGANIC & PARTICULATE FOULING CAN BE CONTROLLED BY MEMBRANE SELECTION AND OPTIMIZED OPERATION/CLEANING PROCEDURES

Optimized Pretreatment selection, design & operation is the key to fouling prevention

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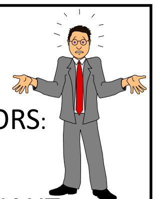
HOW TO PREVENT FOULING AND SCALING ?

- CONTINUOUSLY MONITOR RAW WATER
- KEEP PRE-TREATMENT CLEAN
- MONITOR FEED WATER CHANGES
- FLUSH SYSTEM IF NOT IN USE
- FOLLOW CLEANING PROCEDURES
- PERFORM TREND ANALYSIS
- CONDUCT PROFILING (sample each vessel)
- PERFORM PROBING (if necessary)
- ROUTINE SDI TESTING

85

WHICH ONE TO USE?



DEPENDS ON MANY CRITICAL FACTORS:

- SIZE, TYPE & CONC. OF CONTAMINANT
- POLYAMIDE MEMB. WILL BE DAMAGED BY CL2
- BIOLOGICAL DEGRADATION CONCERNS
- PH, TEMP, FLUX & OTHER DESIGN FACTORS
- AVAILABILITY FOR CONFIGURATION

86

Sanitary Deficiencies– Membrane Filtration

1. Type of membrane used and intended purpose?
2. Type of pretreatment?
3. Safeguards to warn operators of membrane failure?
4. Fouling rate and life of the membranes?

87

Sanitary Deficiencies– Membrane Filtration

5. Percent recovery and technique used for backwash?
6. Frequency of cleaning and disposal of cleaning fluids and brines?
7. Condition of the plant, gauges and appurtenances?

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SILT DENSITY INDEX

SDI IS AN INDICATOR FOR POTENTIAL MEMBRANE FOULING

89

SDI TEST

- MEASUREMENT IS AT CONSTANT TEMP
- PRESSURE IS 30 PSI
- 0.45 u MEMBRANE FILTER
- MEASURE INITIAL ti TO FILL 500 mL GRAD. CYL.
- RUN FOR 15 MINUTES
- MEASURE FINAL tf TO FILL 500 ML GRAD. CYL.

$$SDI = 6.67 - 6.67\ (t_i / t_f)$$

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ACCEPTABLE SDI RANGES

FOR RO <2- 3

FOR NF <3

FOR MF/UF <10 , SOME NO LIMIT

91

Plant Process & Equipment

– Pre-treatment

– Post treatment

– Controls & instrumentation

Custom Plant Designs

+

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OPERATIONAL CHARACTERISTICS

	FLUX	PERM. CONC.
FEED TEMP*. ↑	↑	↑
FEED PRESSURE ↑	↑	—
FEED CONC. ↑	↓	

* ABOUT 3% PER DEGREE CELSIUS

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A FEW OTHER SIDE ISSUES TO KNOW

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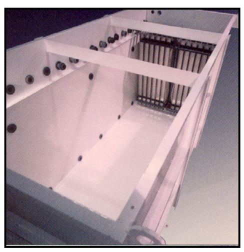
SUBMERGED MEMBRANES ARE THE ANSWER FOR TOUGHER RAW WATERS



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SYSTEM INTEGRITY

EVEN THE LOOSEST MEMBRANES ARE PROVEN BARRIERS AGAINST CRYPTO. & GIARDIA

HOW DO WE ENSURE NO BREAKTHROUGH ?

ARE PARTICLE COUNTERS ACCURATE & SUFFICIENT?

SPECIFY, MAINTAIN & MONITOR “O-RINGS”!!!!!!

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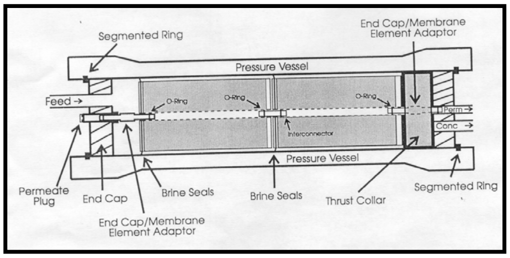
LOTS OF O-RINGS



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IMPACT OF PRE-TREATMENT ON LONG TERM MEMBRANE LIFE

INDUSTRY IS LOOKING AT POLYMERS, POWDER CARBON & COAGULANTS UPSTREAM OF LOOSE MEMBRANES FOR ORGANIC REMOVAL INSTEAD OF TIGHTER MORE EXPENSIVE MEMBRANES.

ALTHOUGH WE ARE SEEING SUCCESS, WHAT ARE THE ADVERSE IMPACTS ON MEMBRANE LIFE?

98

CHLORINE TOLERANT MEMBRANES

INDUSTRY HAS FINALLY REALIZED MOST SURFACE WATER SYSTEMS REQUIRE CHLORINE AT THE HEAD WORKS FOR OXIDATION, DISINFECTION & BIO-GROWTH CONTROL.

NEED MORE CHLORINE TOLERANT LOOSE MEMBRANES WITH HIGHER FLUX RATES

99

CLEANING

- CLEAN WHEN 10-15% DROP IN NORMALIZED FLOW
- ALWAYS FOLLOW MANUFACTURER'S RECOMMENDATIONS
- CHEMICAL IS MIXED & HEATED IN A TANK
- FED AT A RATE OF (40 gpm/VESSEL, 8"ELEMENTS)
- CIRCULATED THEN DISPOSED
- FLUSH
- PUT BACK ON LINE

100

CLEANING

- CLEAN WHEN 10-15% DROP IN NORMALIZED PERMEATE FLOW, OR NORMALIZED DP ACROSS FEED/CONC.
- IF MORE THAN 30% DROP, MAY BE IMPOSSIBLE TO FULLY RESTORE PERFORMANCE
- ALWAYS FOLLOW MANUFACTURER'S RECOMMENDATIONS
- ALWAYS USE THE LEAST HARSH METHOD
- ALWAYS USE PERMEATE IN CLEANING TANK
- CLEANING SOLUTION IS FED AT A RATE OF (40 gpm/VESSEL, 8"ELEMENTS), 50-60 PSI TO MINIMIZE PERMEATION AND FORCING PARTICULATE MATTER INTO MEMBRANE PORES

101

CLEANING CHEMICALS

- DEPENDS ON TYPE & DEGREE OF FOULING AND SCALING
- CONTACT MANUFACTURER OR THIRD PARTY SPECIALTY RO CLEANING FIRMS
- GENERALLY LOW PH FOLLOWED BY HIGH PH (EXCEPTION IS FOR OIL DEPOSITS WHICH IS REVERSED)
  - LOW pH – DISSOLVE SCALANT
  - HIGH pH – ORGANIC REMOVAL
- SOMETIMES SKIDS ARE SOAKED WITH PERMEATE FOR A FEW HOURS BEFORE CLEANING

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CLEANING REMEDIES

- CARBONATE SCALE: EASY TO REMOVE IF DETECTED EARLY, LOW PH WITH CITRIC ACID
- SULFATE SCALE: MUCH MORE DIFFICULT, ESPECIALLY BARIUM AND STRONTIUM SULFATES. BEST IS TO PREVENT FROM HAPPENING
- SILICA: DIFFICULT TO REMOVE IF SILICA GEL COATING HAS HAPPENED
- ORGANIC FOULANTS: IF DETECTED EARLY AND HAVE NOT BEEN ABSORBED TO MEMBRANE SURFACE, NORMAL CLEANING IS SUFFICIENT
- MICROBIAL DEPOSITS: CLEAN, FLUSH, SANITIZE PIPING, PRE-TREATMENT AND DEAD LEGS

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CLEANING PROCEDURE

- FILL CLEANING TANK WITH PERMEATE
- FLUSH TANK & PIPING
- RE-FILL WHILE ADDING CHEMICALS AND RE-CIRCULATING FROM CLEANING PUMP
- ADJUST TEMP. & PH
- CONNECT SKID PIPING & HOSES
- CLEAN ONE OR PART OF A STAGE AT A TIME (PREVENTS FOULANTS FROM FIRST STAGE GETTING INTO SECOND STAGE)

104

CLEANING PROCEDURE (CONT.)

- CLEAN IN THE SAME DIRECTION AS NORMAL FEED TO PREVENT TELESCOPING ELEMENTS
- ENSURE PERMEATE PIPING IS NOT BLOCKED TO PREVENT PRESSURE BUILDUP
- WASTE INITIAL 15-20% PUSHED THROUGH SKID WHICH IS HIGH CONCENTRATED FOULANTS
- RE-CIRCULATE FOR 1-2 HOURS, WHILE MAINTAINING PH & TEMP
- DRAIN & FLUSH WITH PERMEATE
- SAMPLE DRAIN FOR PH & CONDUCTIVITY TO ENSURE ALL DETERGENTS AND CHEMICALS ARE OUT OF SYSTEM

105

CLEANING PROCEDURE (CONT.)

- PUT SKID ON LINE, RUN AT SLOW FEED PUMP SPEED WHILE CHECKING WATER QUALITY. IT MAY TAKE A FEW HOURS BEFORE PERMEATE QUALITY IS STABILIZED

WEAR SAFETY GLASSES, GLOVES AND PROTECTIVE CLOTHING

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OVERALL SYSTEM CONTROL

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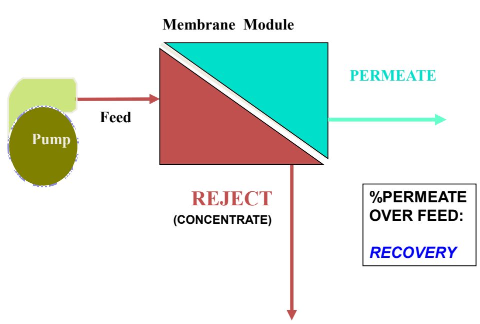
SIMPLIFIED SCHEMATIC



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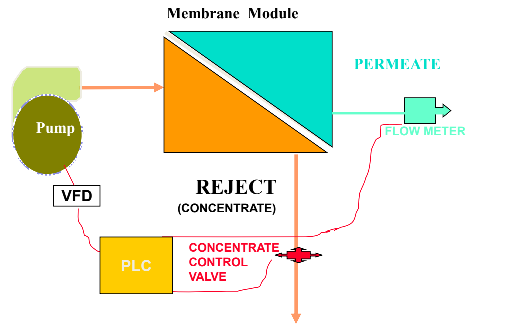
SIMPLE 3 STEP CONTROL

PERMEATE FLOW IS SET
CCV MODULATES TO ACHIEVE DESIGN RECOVERY
FEED PUMP VFD KEEPS UP WITH PRESSURE TO GIVE CONSTANT PERMEATE FLOW



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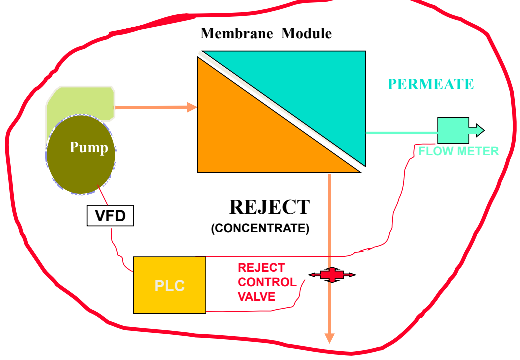
UPSTREAM SEES ONE GIANT CONTROL VALVE



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