AWT Training Seminars

AWT
ASSOCIATION OF WATER TECHNOLOGIES

AWT Training Seminars

SOLIDS/LIQUID SEPARATION
MICRO FILTRATION/ULTRA FILTRATION (MF/UF)

Pretreatment/Post Treatment for Industrial Process and Drinking Water.
Also, for Water Reduction, Recovery and Reuse Applications

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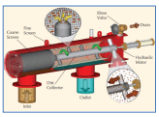
SOLIDS/LIQUID SEPARATION
MICRO FILTRATION/ULTRA FILTRATION (MF/UF)

BRUCE KETRICK discussed MACRO FILTRATION,
(aka PARTICLE FILTRATION) i.e.



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MICRO FILTRATION/ULTRA FILTRATION (MF/UF)

BRUCE KETRICK discussed MACRO FILTRATION, i.e.
Filtration from, perhaps 100-200 µ down to 1-2 µ

Filter types include: Mesh screens, Disc and Self-Cleaning filters, Cartridge and Bag filters, Media filters

Media includes:

- **Sand, Pumice, and Multimedia (sand, anthracite, garnet)**
- **Carbon, Zeolites, Absorbent Clays (e.g. MAR and Biomin) and Molecular sieves**
- **Manganese greensand, BIRM, Filox, KDF, MTM, Pyrolox**
- **Alumina, Calcite, Magnesia, Walnut shell, Bone char**
- **Powdered ion-exchange resins, and Precoats such as Diatomaceous earths (e.g. Kieselguhr)**

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MICRO FILTRATION/ULTRA FILTRATION (MF/UF)

DICK YOUMANS will discuss NANOFILTRATION and HYPERFILTRATION (aka REVERSE OSMOSIS)
Filtration of perhaps 0.001-0.0005 µ (NF) and <0.0001 µ (RO)

NF and RO are types of MEMBRANE TECHNOLOGY



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SOLIDS/LIQUID SEPARATION
MACRO (PARTICLE) FILTRATION AND NF/RO

- **Macro filtration is often used for solids/liquid separation in cooling towers, filtering well water , or as a pre-treatment to, say, ultrapure water production**
- **We can use RO for, say, HP boiler feedwater and, starting with city water we only need a pressure of 250 psi, and can easily get down to 1-10 µS/cm, with perhaps 70% recovery**
- **However, if we use seawater RO (SWRO) for production of, say, drinking water, then we need >1000 psi and can only get to a purity of 500-800 µS/cm, with 30-35% recovery.**

SO WHERE DOES MF/UF FIT IN THE FILTRATION SPECTRUM?

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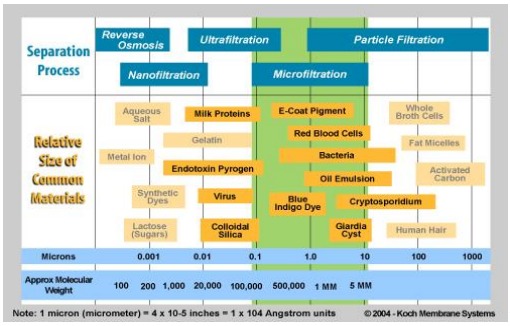
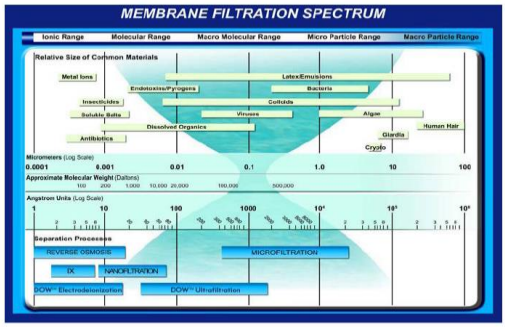
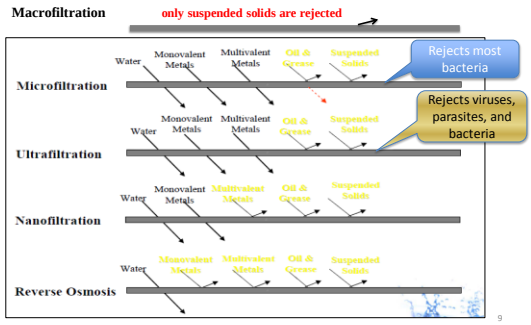
WHERE DOES MF/UF FIT IN THE FILTRATION SPECTRUM?



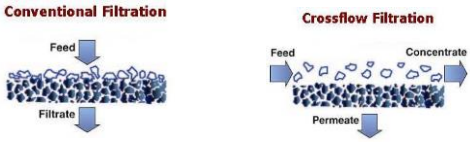
THE FILTRATION SPECTRUM MESSAGE AGAIN!



MEMBRANE PROCESS CHARACTERISTICS



FLOW PATTERNS FOR MACRO FILTRATION AND NF/RO



- Most Conventional (macro /particle) filtration flows by pressure or gravity down through the media, but some systems (e.g. some cartridge filters) can flow upwards.
- All NF/RO membrane technology systems use cross flow filtration. The fluid feed stream runs tangential to the membrane, establishing a pressure differential across the membrane causing some of the particles to pass through the membrane. Remaining particles continue to flow across the membrane, "cleaning it".

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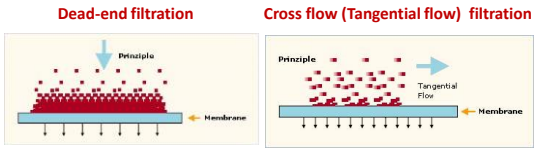
FLOW PATTERNS FOR MF/UF



- Manufacturers of MF/UF membrane modules choose either Dead-end or Cross flow.
- With dead-end filtration all the fluid passes through the membrane and all particles larger than the pore sizes of the membrane are stopped at its surface. This means that trapped particles can start to build up a "filter cake" on the membrane surface, which reduces filtration efficiency until the filter cake is washed away in a special back flushing/rinse cycle.
- In contrast to the dead-end filtration technique, the use of a tangential flow will prevent thicker particles from building up a "filter cake".

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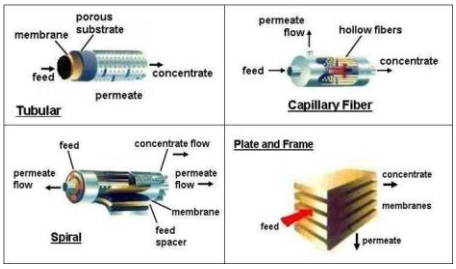
MF/UF MEMBRANES ARE USUALLY A CAPILLARY FIBER TYPE IN A MODULE, OR SHEET TYPE IN A PLATE AND FRAME – OR EVEN TUBULAR



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MF/UF CAPILLARY MEMBRANES LOOK LIKE STRAWS. INSIDE TUBES CAN BE 0.8-0.9 MM (DRINKING WATER) OR 1.2-1.3 MM (INDUSTRIAL WATER)

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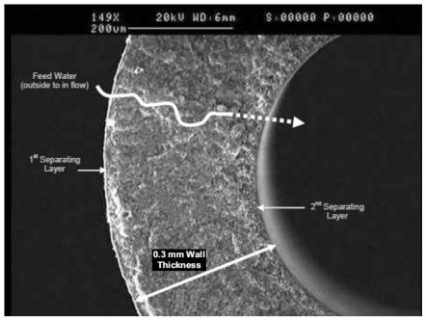
WALL CROSS SECTION OF HOLLOW FIBER



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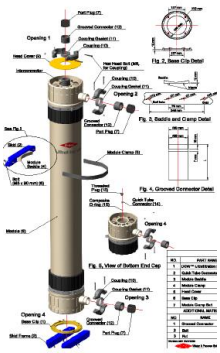
MF/UF MODULE



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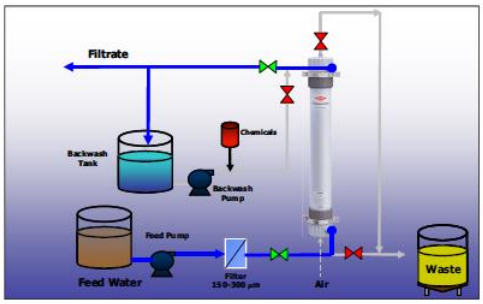
FILTRATION PROCESS USING MF/UF MODULE



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CLEANING PROCESS FOR MF/UF MODULES

- At initial start up modules are forward flushed
- Operation mode is typically from 20 to 60 minutes with 100% of feedwater converted to filtrate, before transmembrane pressure (TMP) rises and a backflush sequence (of typically approx. 2-3 minutes) is triggered.
- Backflush is automatic. Typically, 20-30 second air scour is first – flushing from outside of fibers with discharge through top of module
- Next is draining by gravity. Then backwash reverses filtrate flow (from, say, inside to outside) and removed through top drain
- A second backwash passes through the bottom drain. These can be repeated. A final forward flush removes any trapped air before returning to operating mode.
- A chemical enhanced backwash (CEB) is also usually given periodically, using filtrate and either acid/base, plus oxidant
- CEB chemical is fed into first stage backwash water, then a soak (5-20 mins) is added after the second backwash step.
- CIP acid/caustic operations are usually given every 1-3 months to clean the fibers. Backwash is given 6-8 times, followed by 30-60 min recycle, then 60 min soak , further 30 min recycle, air scouring, backflushes, and final forward flush

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MEMBRANE PORE SIZES

- Expressed as nominal molar mass (Mol. Wt.)
- Nominal pore size or Mol. Wt cut off (MWCO)
- Remove 90% of material of that size.
- Pore size Variability:
- Various types of membrane materials
- Various manufacturing processes for tubes, flat sheets
- Air casting, immersion casting & melt casting.

- MF & UF used for separation of fine suspended solids, microbes, dairy whey, drinking water
- MF is a substitute for multimedia filters in cooling water
- UF needed for macro-molecules. Used to recover backwash water and pretreatment for RO systems

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MEMBRANE POLYMER MATERIALS

- Polyamide (PA)
- Polycarbonate (PC)
- Polyethylene-terephthalate (PET)
- Polysulfone (PS).
- Polyether-sulfone (PES).
- Polyacrylonitrile (PAN) – UF Only
- Polyvinylidene fluoride (PVDF).
- Polyethylene (PE) & -propylene (PP) – MF Only.
- Polytetrafluoroethylene (PTFE) – MF Only.
- Cellulose acetate/nitrate (CA/CN) .
- Ceramics *-for high resistance, but needs high flux rate to compete with polymers, so must have low NTU feedwater*

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TUBULAR MEMBRANES

- MF/UF systems operate at high efficiency & low pressures
- Typically use PES or PVDF membranes
- Can handle high-solid streams such as fruit juices, wine lees, heavy metal hydroxides in wastewater & industrial biotechnology processes
- Modules can enhance color, flavor, and stability without prefiltration, or use of diatomaceous earth or fining agents

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MORE ON MEMBRANE CAPILLARY FIBERS

- Most high flux (HF) membranes are pressure driven inside format (PDI), in which feed enters fiber lumen and driven thru wall, and use PS or PES polymers
- Pressure driven outside format (PDO) have feed entering from outside (larger active membrane surface) and filtrate taken out via internal space (lumen)

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MF/UF MEMBRANE CAPILLARY MODULES

- Most membranes made for inside feed options and have fibers with ID of 0.8-0.9 mm and 1.3-1.4 mm OD.
- OD is at least 2x ID. So OD should be better!
- But in reality, flux rate for PDO is 1.5-2x lower than PDI for a given trans-membrane pressure (TMP), due to lower permeability of outside feed membranes – so flow outputs are similar!
- PES offers a good UF rating and low operating costs due to high permeability. Also, tend to use PDI format, whereby chemicals are contained within lumen. (Tolerates 100 ppm Cl_2)
- PVDF offers robustness due to strength/flexibility, and tolerance for high solids. Tend to use PDO format for scouring control. (Tolerates 20,000 ppm Cl_2)

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MF/UF MEMBRANE CAPILLARY MODULES

- 0.5 µ = approx 4000 K Daltons, 0.05 µ = approx 400 K Daltons
- Typical modules: 6 -10" OD x 48 -140" L. Typical flow: 5-30 gpm
- Typical maximum TMP: 0.2-1.4 bar
- Typical max. operating pressure 5-6 bar
- 50% are pressure driven inside (PDI) and 50% outside (PDO)
- Most membrane materials are either PES or PVDF
- Equal split between Crossflow and Dead-end
- Most MF are 0.1 -0.2 µ
- Most UF are 0.01-0.02 µ
- Both 4 log removal value (4LRV) and 99.99% removal of microorganisms
- UF provides absolute 4 log removal of virus
- Ceramics are often monoliths with large tubes bound within porous $A_{l2}O_3$ substrate
- PES has better wetting than PVDF, also better strength, but less flexibility (so PVDF is higher cost but better for backwashing, and accepts air scouring during industrial applications)
- Hydrophilic CA ...PAN ....PES...PS...PVDF...PE...PP ...Hydrophobic

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MF/UF MEMBRANE CAPILLARY MODULES

Company	MF/UF	Element Description	Brand	Module
Memtec *Sintered substrate*	MF	10x 1" tubes	S5	6" x 72"
	MF	4x 1" tubes	S1	4" x 72"
Koch *200 ppm Cl_2*	MF	19x ½" tubes	Super Cor XLMKF	6" x 139"
	UF	37x ½ " tubes	HFM 513	6" x 139"
Duraflow	MF	13 x 1" tubes	DF 413	6" x 72"
	MF	10 x 1" tubes	DF 415L	6" x 72"
Hydra Nautics	UF	1.2 mm ID Cap	Hydracap 40LD	10" x 48"
	UF	0.8 mm ID Cap	Hydracap 40	10" x 48"
QUA	UF	1.2 mm HF	QSEP3412	9" x 72"
	UF	0.8 mm HF	QSEP 4508	9" x 72"
BASF Inge	UF	1.5 mm HF	Dizzer XL25	10" x 47"
	UF	0.9 mm HF	Dizzer XL 38	10" x 47"
Toray	UF	HF (Industrial)	HFU 1020N	8.5" x 44"
	UF	HF(Drinking)	HFS 1020N	8.5" x 44"
DOW	UF	HF SFD = drinking	SFP 2660	6" x 60"
	UF	HF SFD = drinking	SFP 2860	8" x 60"

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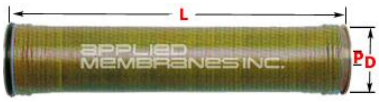
MORE ON MICRO/ULTRA FILTRATION (MF/UF)

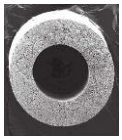
Compare Pore Sizes

- Microfiltration: 0.05 - 1.0 µm
- Ultrafiltration: 0.005 - 0.1 µm (1000 - 500,000 MWCO).
- Nanofiltration: 0.001 – 0.01 µm (200 – 10,000 MWCO).
- Reverse Osmosis: 0.0005 – 0.002 µm.

MF Is now widely used for pretreatment to RO. Permeate turbidity levels usually below 0.4 NTU. Very reliable. Needs some chemical treatment and microbiological control, but MF delivers consistent results.

Also, MF is very useful for side-stream removal of suspended solids removal from cooling water systems, where it replaces sand/multi-media filters, giving improved filtration to a lower micron range.





PVDF Microfiltration membrane element: 40" L x 8"D. Individual hollow fiber

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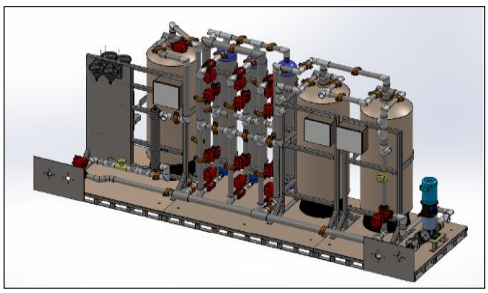
QUA UF FIBER DRINKING WATER SYSTEM FOR IRAQ



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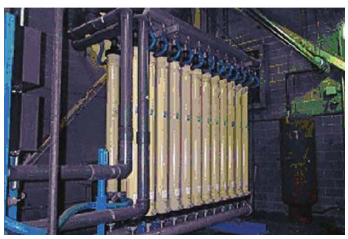
PALL MICROFILTRATION MEMBRANE RACK



300 GPM MF RACK WITH 24 HOLLOW FIBER MODULES. – *for water reuse!*

MF IS NOW RENDERING SIDE-STREAM SAND/MEDIA FILTRATION OBSOLETE, DUE TO SAVINGS IN BACK-WASH WATER, AND AS A PRE-TREAT TO RO FOR BLEED WATER RECOVERY

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ULTRA FILTRATION (UF) IS THE EMERGING TECHNOLOGY FAVORITE FOR REMOVAL OF OIL AND BIOLOGICAL CONTAMINANTS FROM WATER (e.g. KOCH)

- All membrane-based separations of liquids from solids have enjoyed increasing popularity over the last 20 years, due to continual product improvements, although UF (like NF/RO etc.) can be subject to fouling problems from some oily wastes, requiring a CIP.

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V-SEP UF TECHNOLOGY

- Fouling is due primarily to the formation of a boundary layer that builds up naturally on the membranes surface during the filtration process.
- In addition to cutting down on the flux performance of the membrane, this boundary or gel layer acts as a secondary membrane reducing the selectivity of the membrane in use.
- However vibrating UF systems can over come this problem

UF plants are often built with hollow fiber outside-in membranes, and used to purify surface, waste, or ground-water from suspended solids, colloids and all kind of micro-organisms such as bacteria, virus, protozoa, germs and larvae. Also, for oily wastes –but vibrating shear-enhanced (V-Sep) systems work better (expensive but less fouling)!

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MEMBRANE BIO-REACTORS (MBR) ARE REPLACING CONVENTIONAL WW TREATMENT SYSTEMS

- The pretreatment step involves screening out coarse materials. In the biological treatment step, bacteria acts upon the organic materials to break them down.
- The clarifier is used in the final step to separate water from the sludge though sedimentation. Sedimentation, however, is often incomplete with regard to microorganisms.
- Typically the discharge from a conventional plant will contain 10,000 to 100,000 microbes per milliliter

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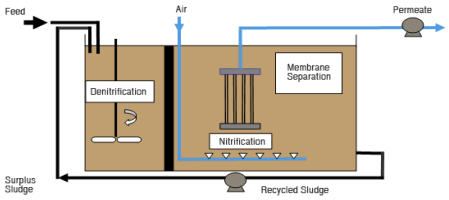
MBR



MBR with PVDF membranes allows reactor tank MLSS >12,000 mg/l as compared to conventional processes which typically operate at MLSS 3-4,000 mg/l). Bacteria and microbes are retained in the reactor tank, which shortens the treatment time.

As a result of the shortened reaction time and elimination of further post treatment, MBR occupies approximately 20% to 30% of the space required by a traditional biological treatment plant.

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UF: ZENON MEMBRANE BIOREACTOR (MBR)

MBR combines clarification, aeration, filtration in one system, using reinforced 0.1µ membranes for N/P removal, RO pretreat, reuse, and direct discharge.

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MBR'S NOW REPLACING CONVENTIONAL TREATMENT SYSTEMS DUE TO 4X LOADING!

Most MBR;s use hollow fiber membranes in sheets, within a plate and frame arrangement. Pretreatment and membrane cleaning are critical issues

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MBR CLEANING REQUIRES AIR SCOURING OF MEMBRANES AND BACK-PULSE CIP

- Conventional membrane bioreactors process immerses membranes directly into highly concentrated mixed liquor suspended solids (MLSS) - 4x normal activated sludge loadings.
- MLSS contains high levels of dispersed , small particles comprised of inert and colloidal material.
- High membrane fouling environment, which results in low membrane flux rates, which require large membrane surface area. Air scouring reduces fouling

BACK-PULSE CIP

EMERGING TECHNOLOGIES NOW INCLUDE CHEMICAL-BASED INJECTION CLEANING, THAT DOES NOT REQUIRE PRIOR MLSS REMOVAL. SAVES TIME AND MONEY !

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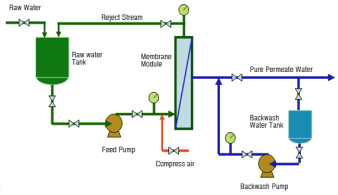
CFM SYSTEMS



Continuous Membrane Filtration (CMF) utilises microfiltration / ultrafiltration membrane to achieve removal of submicron contaminants in water. A typical CMF system is made up of a membrane filtration unit and a membrane cleaning system. Raw water enters the cavity around the hollow fiber membrane which act as a physical barrier. Permeate is drawn from the inner lumen of the hollow fiber membrane either by means of pump, vacuum suction or by gravity. 1-10% reject is recycled and backwash given to maintain flux.

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RECAP: MICROFILTRATION (MF)

PALL CORP. (USA) MEMSTAR (Australia)

- MF is a low pressure 30-100 psig) process for separating larger size solutes from aqueous solutions by means of a semi-permeable membrane. This process is carried out by having a process solution flow along a membrane surface under pressure. Retained solutes (such as particulate matter) leave with the flowing process stream and do not accumulate on the membrane surface.
- Retains large suspended solids
- Passes some suspended solids and all dissolved material
- Pore ranges from 0.1 micron to 0.2 micron

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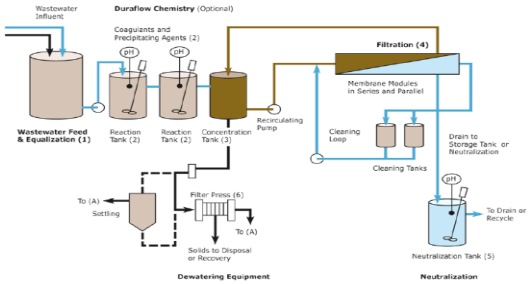
MF BASED SYSTEM FOR WASTEWATER TREATMENT



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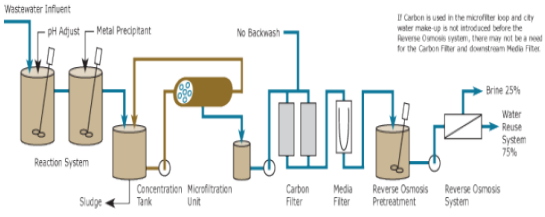
MICROFILTRATION/RO RECYCLE PROCESS



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RECAP: ULTRA FILTRATION

UF FOR INDUSTRIAL WATER/OILY WATER CLEANUP & POTABLE

UF/ MBR FOR WASTEWATER

UF MODULES CAN BE JOINED TO MAKE CASSETTES, WHICH ARE THEN LINKED TO MAKE SYSTEMS. *Use UF for:*

- **Tertiary filtration and treatment of filter backwash**
- **Removal of turbidity, bacteria, viruses and cysts**
- **Removal of Fe/Mn, organics, color, and THM precursors**
- **Retrofit of concentional multi-media filters**
- **Emergency response and mobile water systems**
- **Removal of oil waste –uses vibrating membrane**
- **Pretreatment for RO and other high purity water systems**

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RECAP: MEMBRANE TECHNOLOGIES

- **Microfiltration – food/beverage for clarification, concentration, recovery & sterilization. Also pharma/biotech use. pore sizes = 0.1-10 µ**
- **Ultrafiltration (UF) – separation/concentration of macromolecules and colloids. Pore sizes 1 to 100 nm. Applications include electropaints, gray water, emulsions, oily wastes, milk, cheese and protein processing. Also, a pretreatment "roughing" filter for ion-exchange and EDR, for boiler MU water**
- **Nanofiltration (NF) - softening, removal of color/dyestuffs/ THMs, and treating contaminated ground water. Pore size approx 1 nm. NF rejects Ca/Mg, but not so good with Na/K. Also, drinking water industry**
- **Hyperfiltration (Reverse Osmosis) - is membrane distillation/ desal/ desalting. Pore sizes 1 to 10 Angstrom units. ALL RO plants susceptible to fouling, so adequate pretreatment and operation is essential**
- ***Note: Different membrane manufacturers produce loose/tight pore size variations with different MW cut off points and PDI/PDO designs. There is no standardization!***

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