Application of Alternative Pretreatment Technologies for Low Pressure Membranes in Water Treatment

BROWN AND CALDWELL

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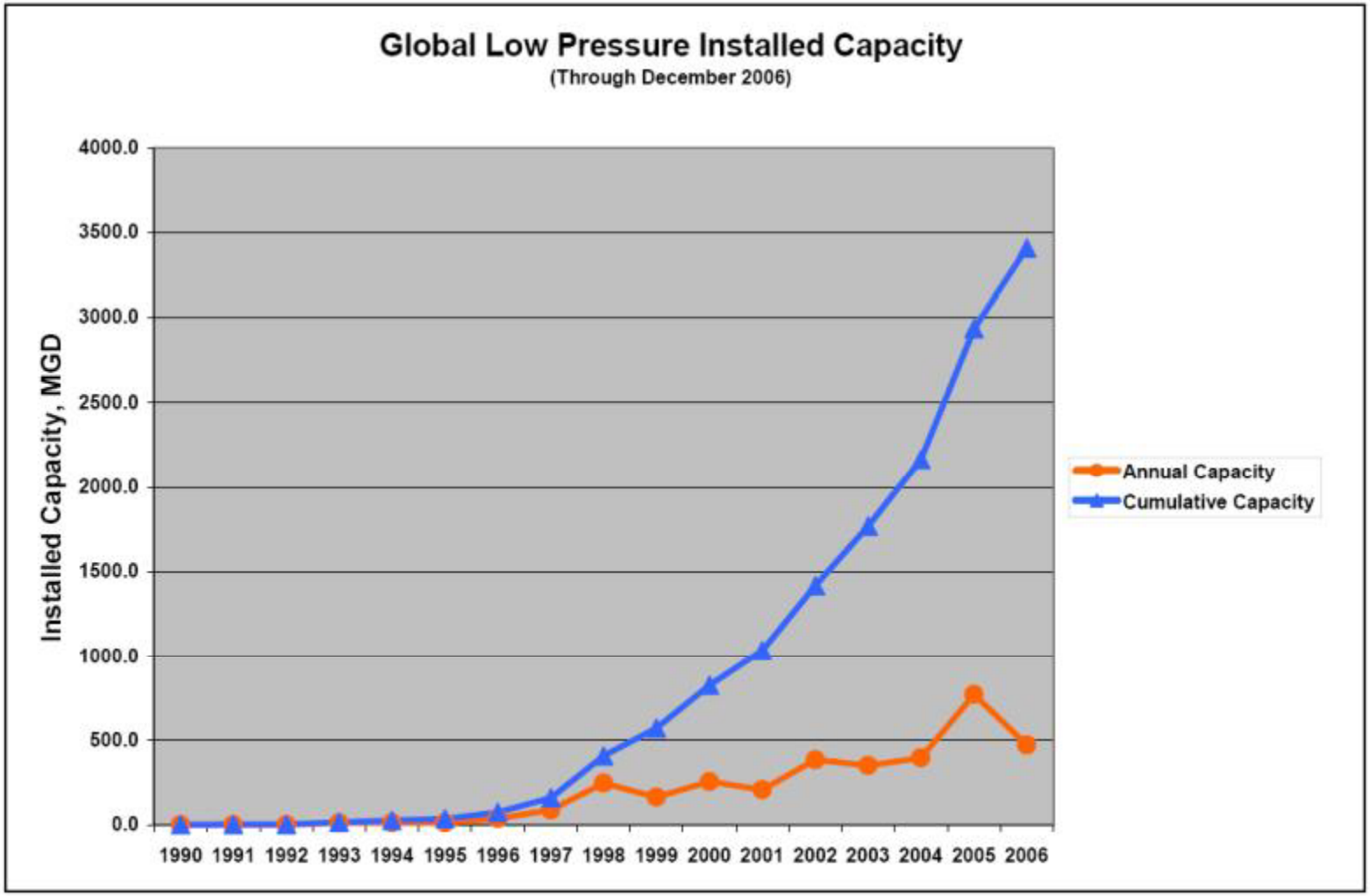
Low Pressure Membranes

- Microfiltration (MF) Pore Size: 0.1–0.5 μm
- Ultrafiltration (UF) Pore Size: 0.01-0.05 μm
- Typical Feed Pressure <50 psi w/ Exceptions
- Remove Particulates and Microbials
- Do not Remove Dissolved Constituents
- Applied to Drinking Water Treatment Since Early 1990's (Mostly Hollow Fiber MF/UF)
- First Significant U.S. Plant (3.6 mgd) in Saratoga, CA in 1993

Drastic Increase in Low Pressure Membrane Installations in the Last 10 - 12 Years

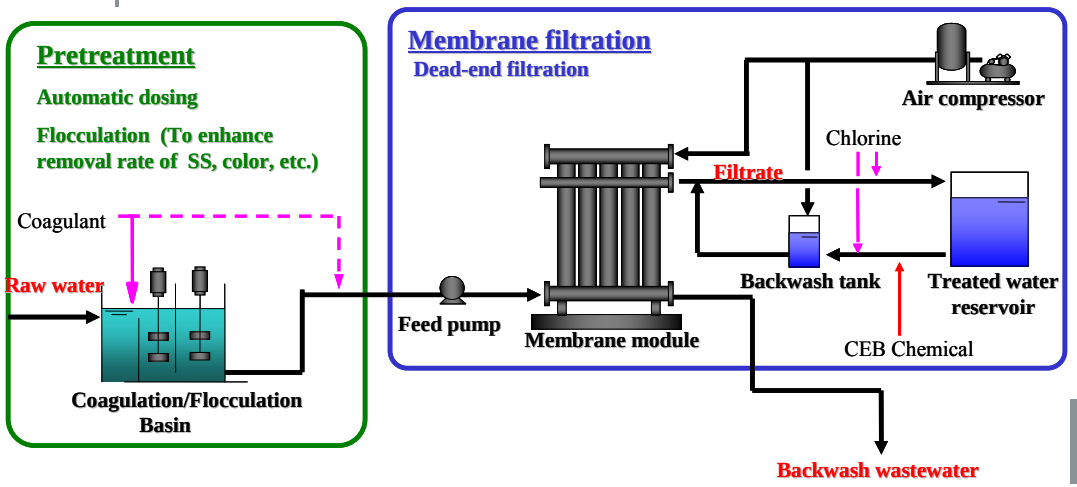


Microfiltration vs. Ultrafiltration in Removal Efficiencies

Microbe	Microfiltration	Ultrafiltration
Giardia Cysts	4.5-7 log	5-7 log
Cryptosporidium	4.5-7 log	5-7 log
MS-2 Bacteriophage Virus	0.5-3.0 log	4.5-6 log
Particle Counts >2 micron 2-5 micron 5-15 micron	 <10/ml <10/ml <1/ml	 <10/ml <10/ml <1/ml
Turbidity - Average	0.01-0.03 ntu	0.01-0.03 ntu

Why is Pretreatment Needed?

- Iron & Manganese Removal
- Arsenic Removal
- Taste & Odor Removal
- DBP Precursor Removal
- Color Removal
- Foulant Reduction
- Optimize Membrane Flux and Maintenance
- Overall Life Cycle Cost Reduction



Water Classification vs. Pretreatment

	Groundwater	Groundwater	Surface Water	Surface Water	Secondary Effluent
Parameter	Under the Influence of Surface water (LT2)	High Iron and Mn	Low TOC or Turbidity (LT2)	High TOC or Turbidity (LT2)	Secondary Wastewater Effluent
Contaminants	Turbidity& Microbial Pathogens	Iron and Mn	Turbidity & Microbial Pathogens	Turbidity & Microbial Pathogens	SS & Pathogens
Pretreatment	None	Direct Oxidation & Precipitation	None (400 µm strainer)	Direct Coag. OR Coag. & Clarif.	Disinfection & Strainer
Filtered Water Quality	<0.05 NTU ND Giardia & Crypto	<0.05 NTU Fe & Mn <0.05 ppm	<0.05 NTU ND Giardia &Crypto	<0.05 NTU ,ND Giardia &Crypto, 35 % Reduction of TOC	SDI<2 <0.05 NTU

Alternative Pretreatment Technologies for MF/UF

- Simple Straining/Screening
- Inline Coagulation or Oxidation
- Coagulation-Flocculation (CF)
- CF with Conventional or Plate Settler
- CF with Solids Contact Clarifier
- High-Rate Clarification (e.g. Actiflo®)
- High-Rate DAF (AquaDAF™, Clari-DAF™)
- Lime Softening
- Magnetic Ion Exchange (MIEX®)
- Powdered Activated Carbon (PAC)

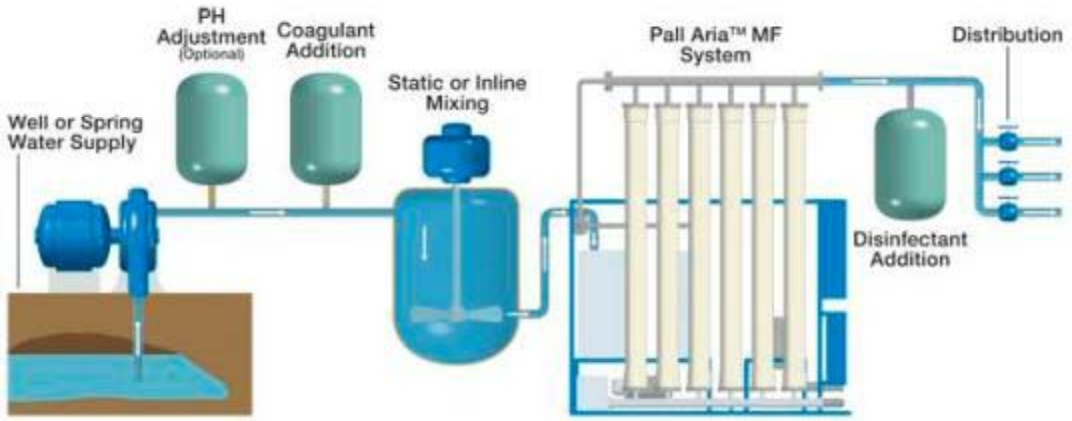
Prefiltration Strainers/Screens

- To Protect Hollow Fibers from Plugging by Larger Particles
- Pore Size: 100 – 500 μm
- Automatic Backwash/Self Cleaning
- Some Typical Vendors
  - Amiad Filtration Systems
  - Fluid Engineering
  - Hayward Strainers

Groundwater Treatment for Manganese and Arsenic Removal

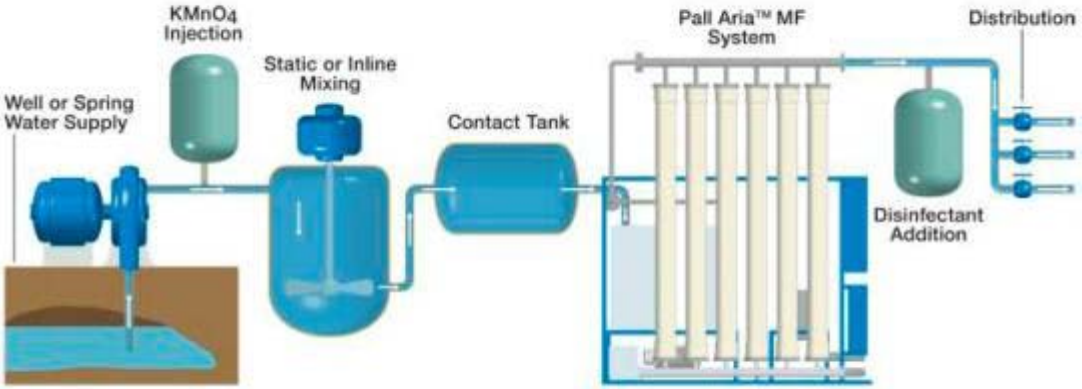
ARSENIC REMOVAL

- Soluble Arsenic is removed using ferric hydroxide to complex the arsenic. MF provides “the barrier” and removes the arsenic floc particles.
- This approach is cost competitive with adsorptive media and provides lower O&M (regeneration / disposal of media).



MANGANESE REMOVAL

- Soluble Iron and Manganese are removed by oxidization. MF provides “the barrier” and removes the precipitated iron/manganese to < 0.05 mg/L.
- PVDF membranes can handle a variety of oxidants.



Treatment of Surface Waters: Direct Coagulation or Coag/Clarification

- Both Can Remove DBP Precursors
- Similar Membrane Effluent Quality
- Full Pretreatment: Higher Flux, Lower Fouling Potential, Less Upsets, Lower Life Cycle Cost for Larger Systems, etc.
- Small Systems May Favor Less Equipment
- Membrane Limitations for Feed Water Quality

ZW1000 & ZW1500 Positioning

	ZW1000	ZW1500
Direct Filtration Average Turbidity	< 50 ntu	< 50 ntu
Enhanced Coagulation Average Dose (mg/L)	< 40 mg/L	< 40 mg/L
Tertiary Treatment Average TSS (mg/L)	< 30 mg/L	< 30 mg/L
Sea Water Average TSS (mg/L)	< 50 ntu	< 50 ntu

Options for best site-specific solution

DOW™ UF – Product Specs

Typical Process Conditions		
	SI	**US**
Maximum Operating Transmembrane Pressure (TMP)	2.1 bar	30 psi
Maximum Backwash Pressure	2.5 bar	36 psi
Backwash Flux	100–150 L/m²h	59–88 gfd
	Maximum	**Typical**
Turbidity	300 NTU	<50 NTU
Total Suspended Solids (TSS)	100 ppm	<20 ppm
Particle Size	300 μm	≤150 μm
Backwash Frequency	20 to 60 minutes	

Case Study: City of Clovis, CA

- A New 15 MGD Water Treatment Plant
- Rush Schedule for Construction
- Enterprise Canal Water Quality
  - Turbidity: Avg: 8.62 NTU, Max: 138 NTU
  - Color: Avg: 45.3 PCU, Max: 550 PCU

- Recommended Process Scheme: Membrane Filtration w/ Full Pretreatment

Full Pretreatment Alternatives

- Coag/Floc/Conventional Sedimentation
- Coag/Floc/Plate Settler
- Coag/Floc/Dissolved Air Flotation
- Actiflo® (Ballasted Flocculation)

Cost Comparison

Table 2.0: Clarification Cost Evaluation

	Conventional	Plate Settlers	DAF	ACTIFLO
Capital Cost [1]	$1,900	$1,700	$1,825	$1,575
O&M [2]	$2,332	$2,264	$2,774	$2,261
20 Year PWC	$4,232	$3,964	$4,599	$3,836

All values are in thousand

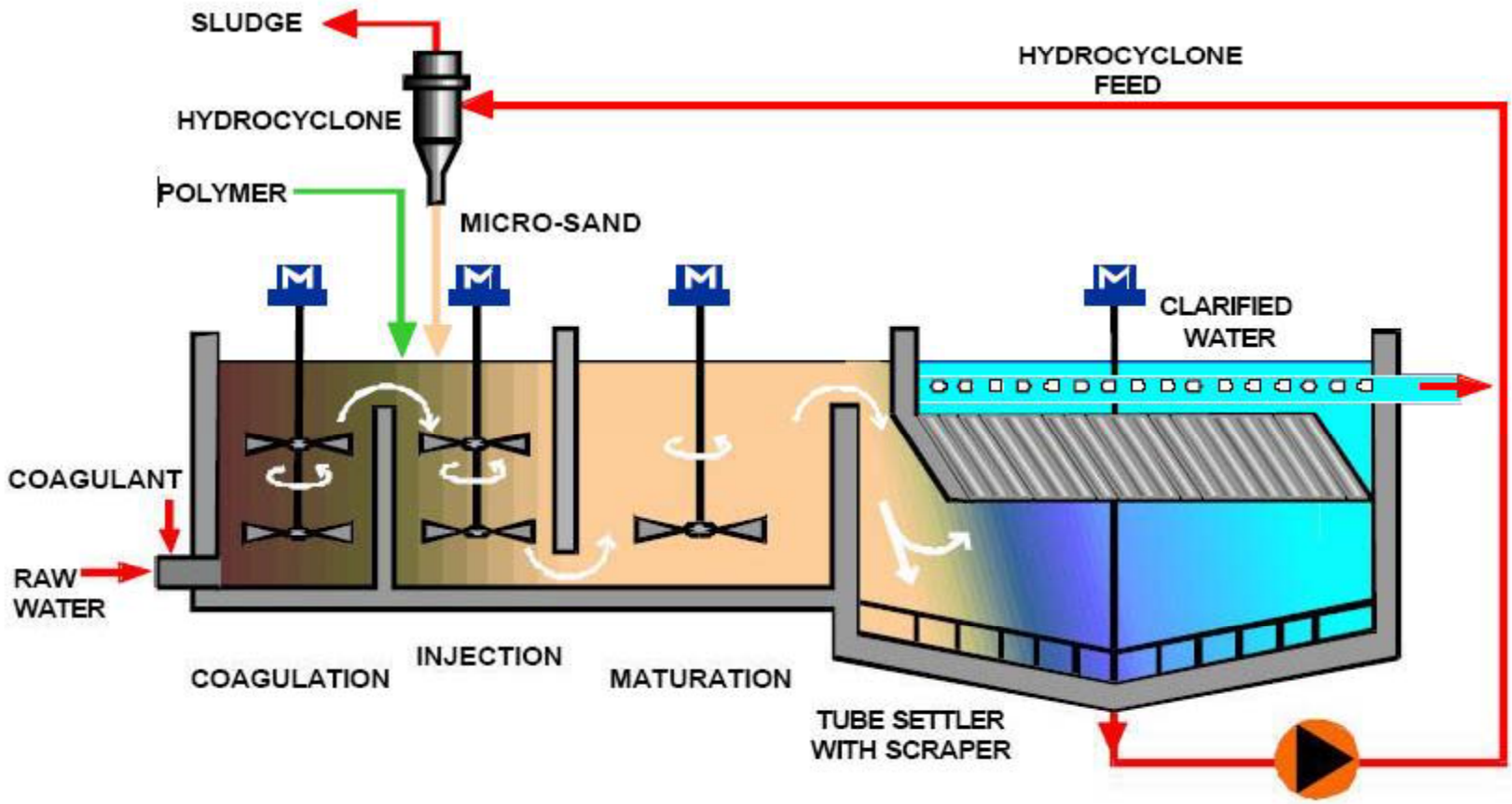
1 Capital cost includes equipment, concrete, and installation

2 O&M includes chemical, energy, maintenance, and labor

Reasons for Selection of Actiflo®

- Lowest Present Worth Cost
- Compactness
- Fast Schedule Using Packaged Units
- Used Successfully in a Neighboring City with Similar Water Source (Pretreatment for Conventional Filtration)
- Used Successfully as Pretreatment for Koch UF Membranes in Cass County, MO

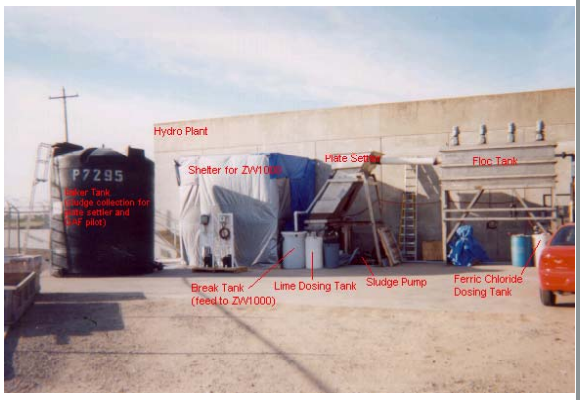
Actiflo® Flow Diagram



Operating Problems

- Polymer Carryover
- Microsand Carryover
- Fouling of Membranes

Case Study: South San Joaquin Irrigation District Surface WTP

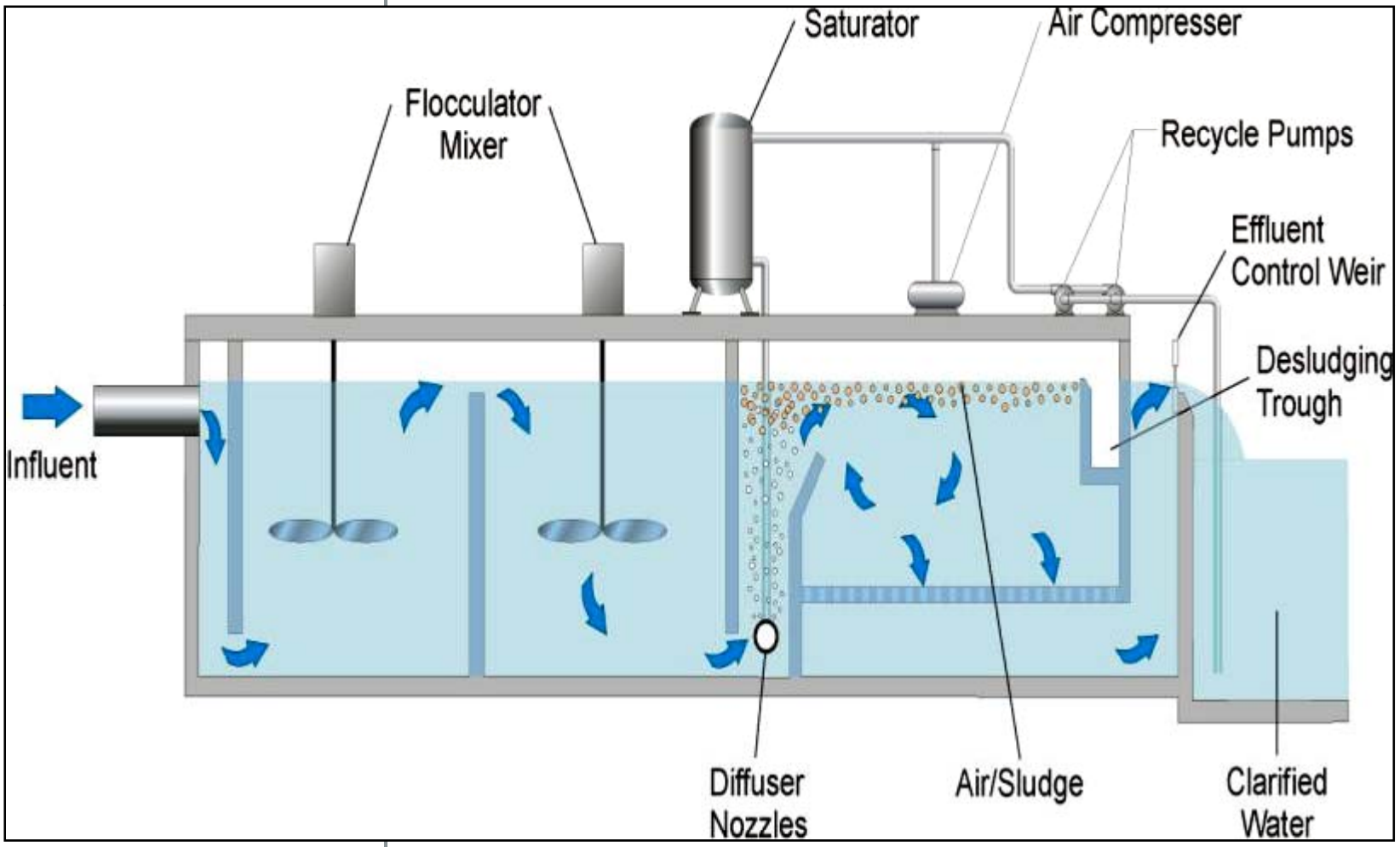


- New 40 MGD Surface WTP
- Potential Algae in Raw Water
- TOC Removal for DBP Control
- ZW 1000 UF Pre-selected by Bidding
- Proof Pilot w/ 2 Pretreatment Alternatives
  - CF/Plate Settler
  - AquaDAF™

Comparison of Plate Settler and AquaDAF™ Pilot Performance

	Plate Settler	AquaDAF
$FeCl_3$ Dosage, mg/L	15	10
SLR, gpm/sf	0.65	14
Effluent Turbidity, NTU	1-2	0.5
TOC Removal, %	18	>30

AquaDAF™ Process Flow Diagram



Full Scale AquaDAF™ Basin

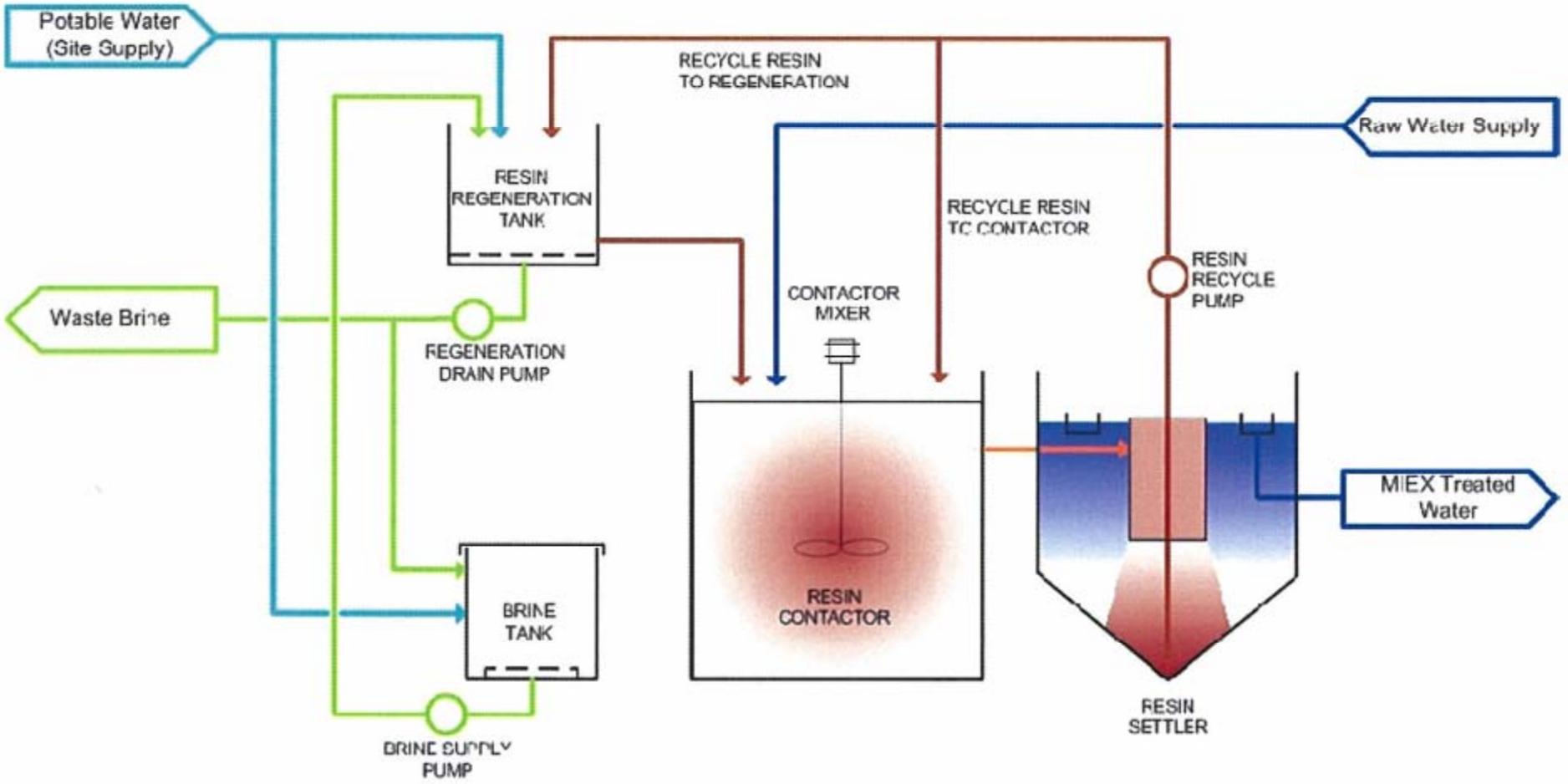
Full-Scale Performance AquaDAF Effluent Turbidity (0.499 NTU Average)

Full-Scale Performance - UF Effluent Turbidity (0.017 NTU Average)

Other Pretreatment Applications

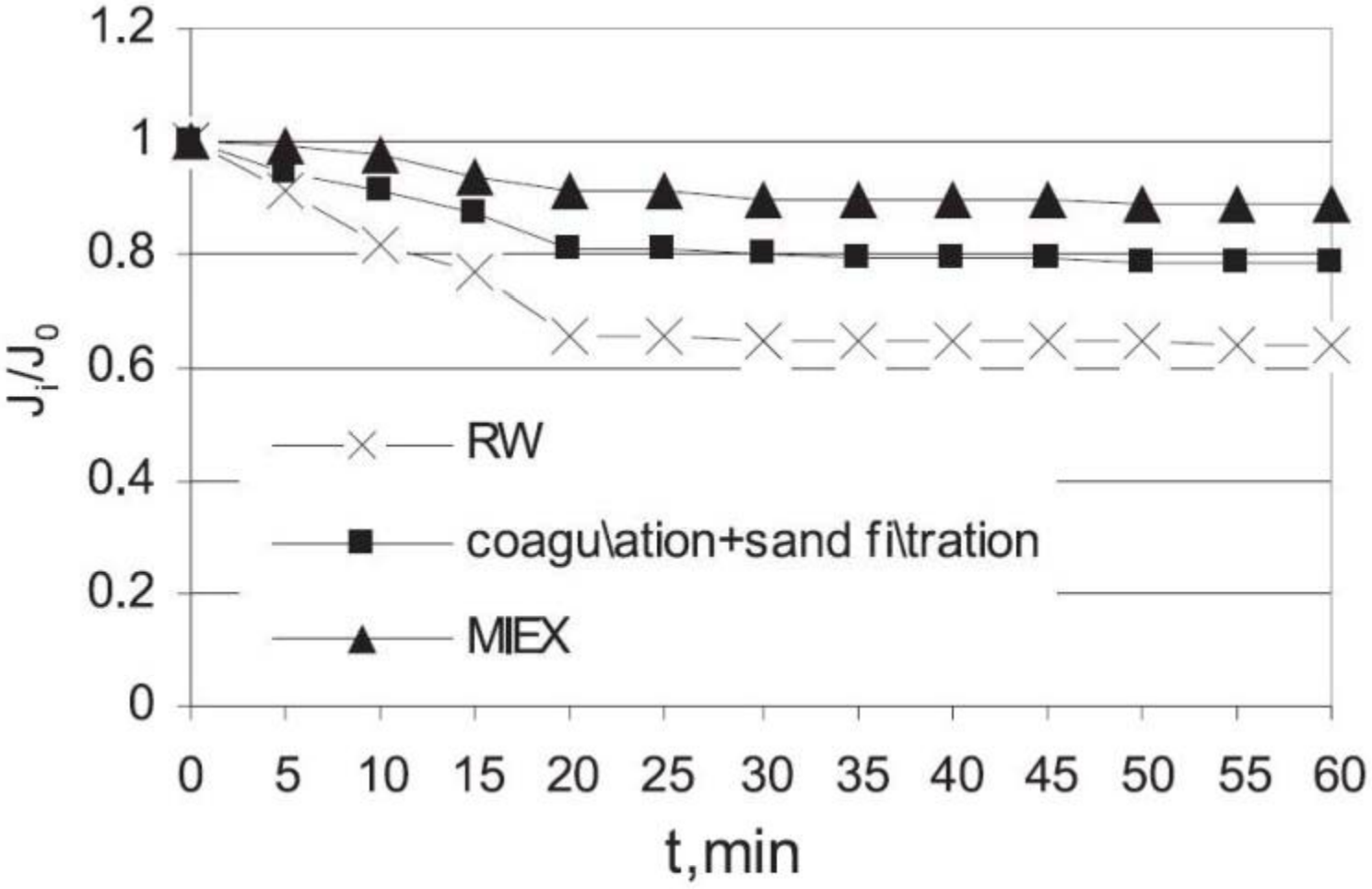
- Direct Coag w/ or w/o Floc: Many Successful Plants for DBP and Foulant Reduction
- CF/Solids Contact Clarifier: Mostly Existing
- CF/Plate Settler: The Safe Choice
- Lime Softening: Mostly Pilot Data, Improve Flux, $CaCO_3$ Deposition a Concern
- PAC: Remove T/O but Decrease Flux, Better with Cross-Flow Membrane Operation
- MIEX®: Improved MF/UF Operations by Removing Small Molecule Organics

Simplified MIEX® Process Flow Diagram



Source: Orica Watercare, Inc.

The Influence of Feed Water Pretreatment on Permeate Flux Decline



Summary and Conclusions

- Low Pressure Membranes (MF/UF) are Becoming the Filtration Process of Choice in Most New Drinking Water Treatment Plants
- Most of the Recent MF/UF Systems Have Pretreatment besides Straining
- Selection of Pretreatment Alternatives Depends on Raw Water Characteristics, Treatment Objectives, Overall Life Cycle Cost, Reliability
- Pilot Testing is Recommended for Most Cases