CornellEngineering

Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

Topic: MF/UF Membranes Design

Instructor: YuJung Chang

YuJung.Chang@aecom.com

Class #15 10/22/2018 2:55 – 4:10pm

Homework for Class #15

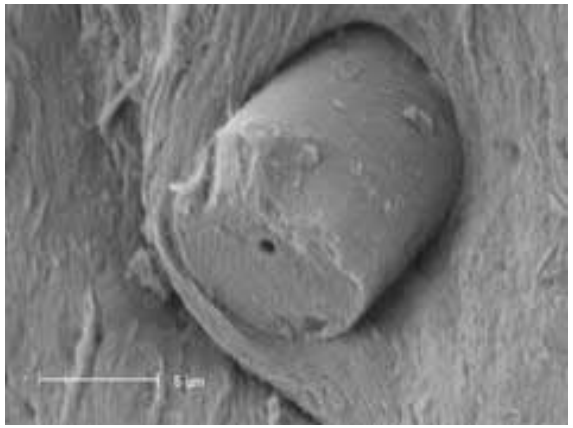
- Provide a Process Design for a 10 mgd membrane WTP
  - Pressurized membrane from Pall
  - Designed for water temperature from 5C – 25C
  - Assuming 40 membrane module per skid
- Provide following design parameters with explanations/justifications
  - Number of membrane skids
  - Number of membrane trains
  - Design Flux (gpm/ft2)
  - List functions and equipment should be included in your design
- Provide at least 2 considerations for Mechanical Design
- Homework Due 10/29

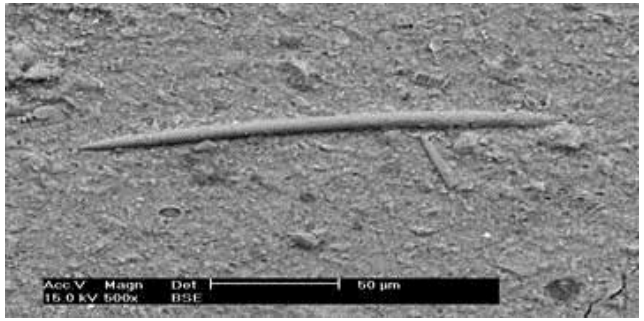
AECOM Imagine it. Delivered.

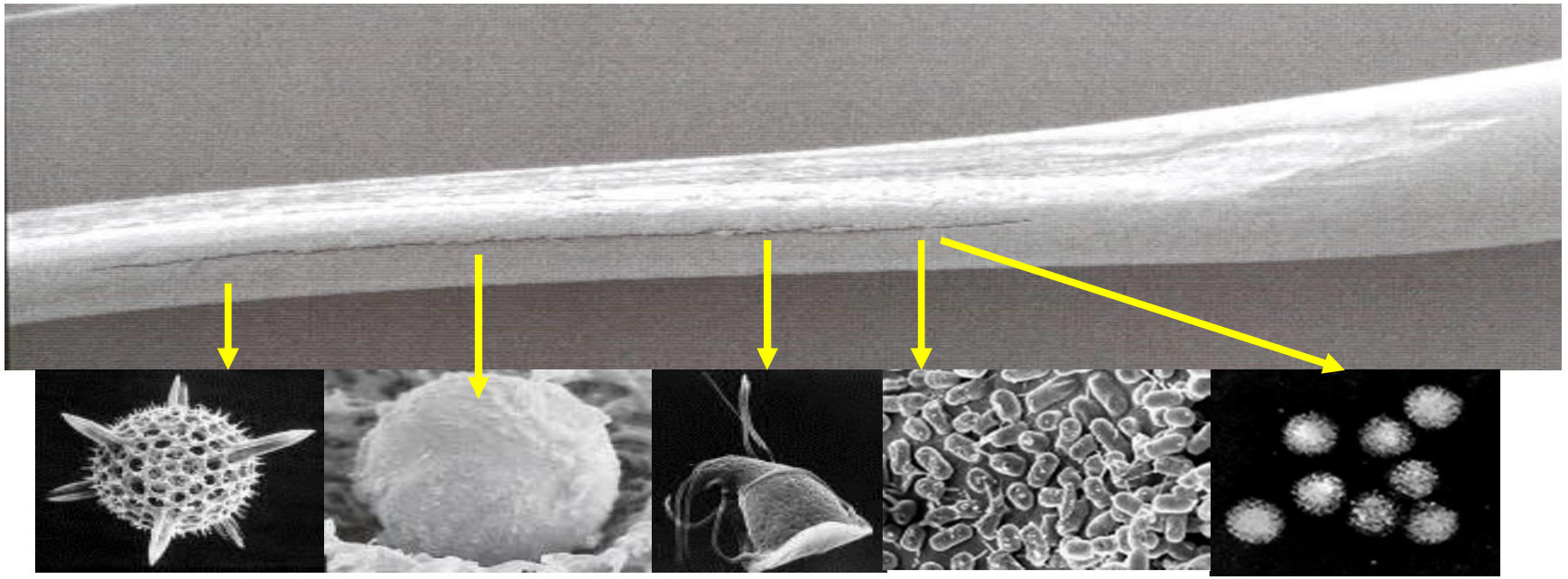
Membrane Basics

Membrane Integrity

Membrane failure is rarely catastrophic – less serious than microbial penetration of rapid sand filter beds.





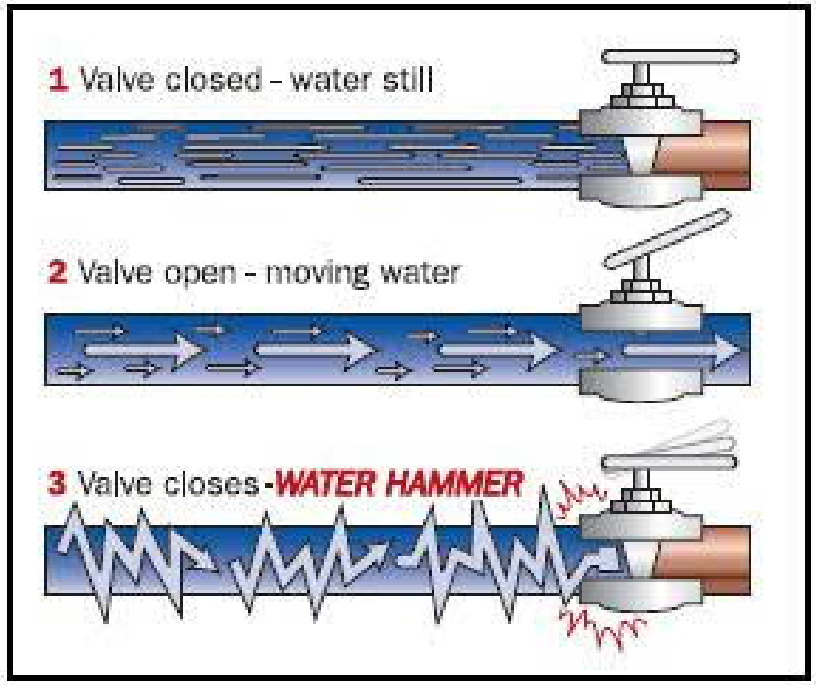


- **Membranes fail incrementally – one fiber at a time, unless for a catastrophic event.**
- **Statistically, individual fiber breaks are insignificant to the overall microbial water quality.**

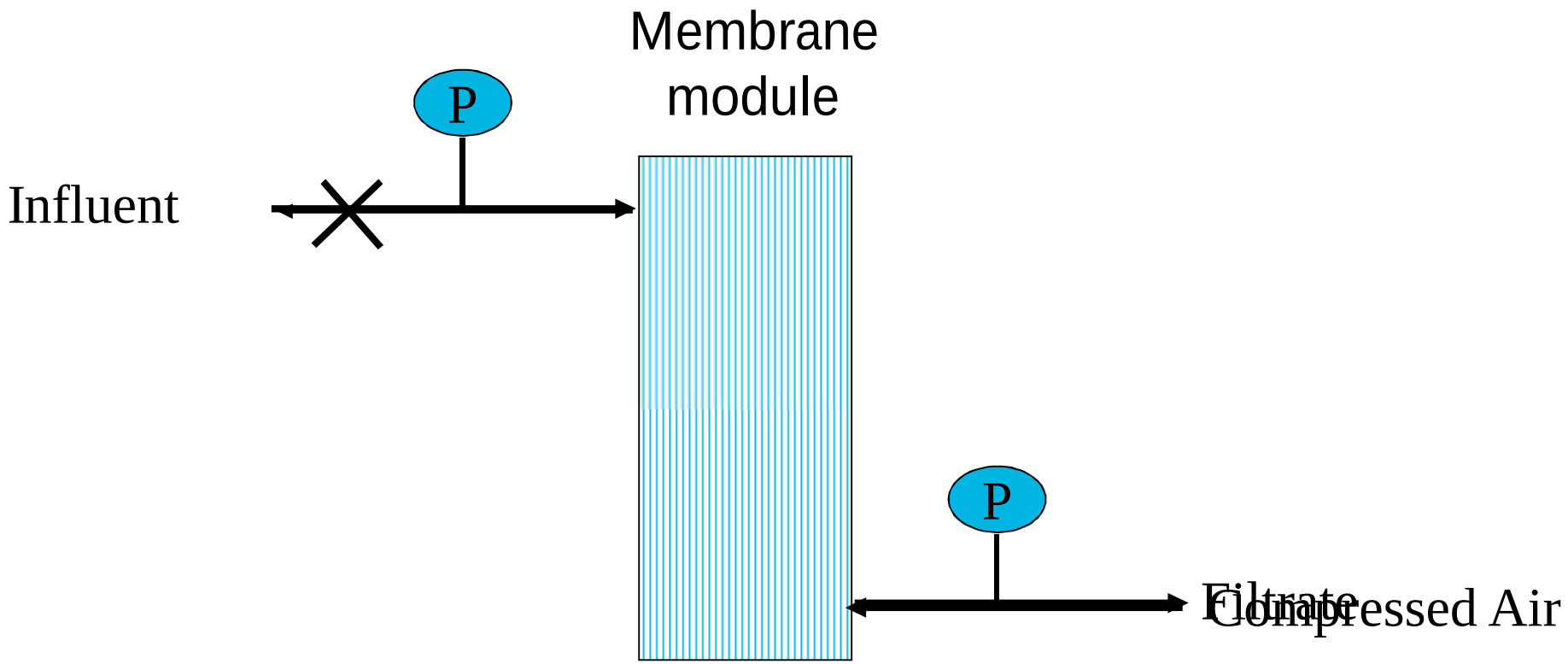
But….. Catastrophic Does HAPPEN!!!!

Deign Consideration: Water Hammer

- There is “momentum” of moving water in addition to static pressure
- Water Hammer happens when Valve closed suddenly
- Valving sequence (open & close valve) was wrong



Pressure Holding Test



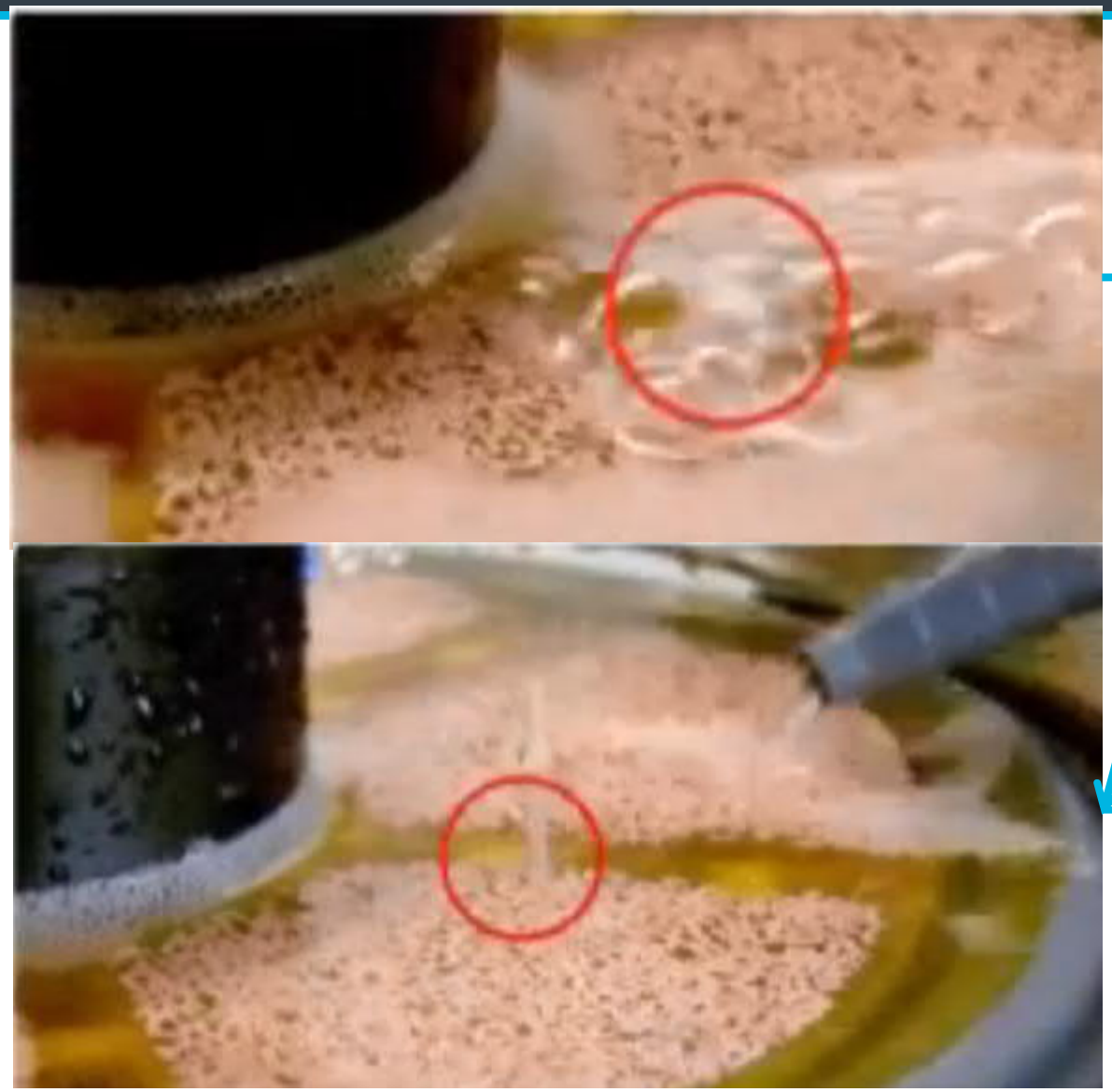
Membrane Integrity Monitoring

- On-Line Turbidity Monitoring
  - 0.08 NTU 95% of the time, 0.1 NTU max.
- On-Line Particle Count (not common anymore)
  - Baseline establishment (< 50 particles/mL)
  - Could be affected by air bubbles
  - Sensitivity: Not sensitive enough (yet) for the detection of a 3 μm breach
  - Too easy for false alarms
- Pressure Holding Test (Air integrity testing)
  - Direct Integrity Testing is required by EPA
- Virus Seeding Test (UF)
  - Only for initial product verification, cannot be used for continuous monitoring

Membrane Fiber Cut Test

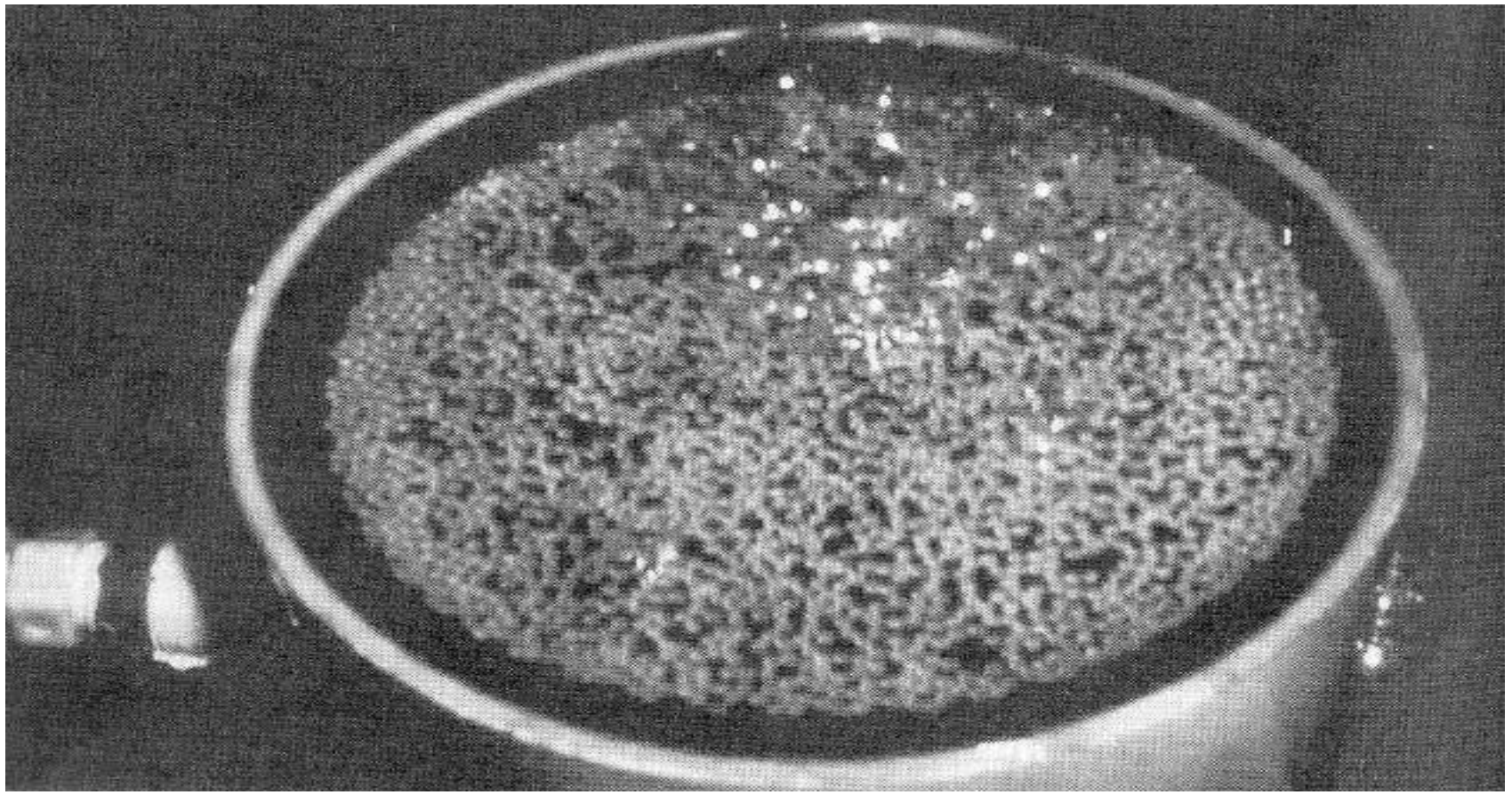
Pre-Cut Membrane Module

Membrane Repair with Pins



Remove Repair Pins

Broken Fiber Identification



Mark the Broken Fiber

Compromised Module

Water Quality with Broken Fiber

	No Broken Fiber			1 Broken Fiber			
Op. Time (min)	5	15	20	5	13	17	23
Feed Turbidity	1.52	1.58	1.58	1.42	1.49	1.47	1.45
Filtrate Turbidity	0.068	0.067	0.067	0.076	0.068	0.068	0.067
Filtrate PC > 2 μm	0.46	0.04	0	9.80	5.08	4.74	5.92

– Although particle count (PC) seems to be sensitive, false alarm from air bubbles render its reliability as a membrane Past/Fail indicator

Module Integrity Inspection

Virus (Pathogen) Seeding Test

All 3 tests at the beginning, the middle, and the end of Performance Testing showed > 5 log virus rejection.

AECOM Imagine it. Delivered.

Membrane Autopsy

Technics to Identify What Went Wrong with Membranes

Objectives of Membrane Autopsy

– It is an effective tool to reveal the natural of membrane fouling & physical damage

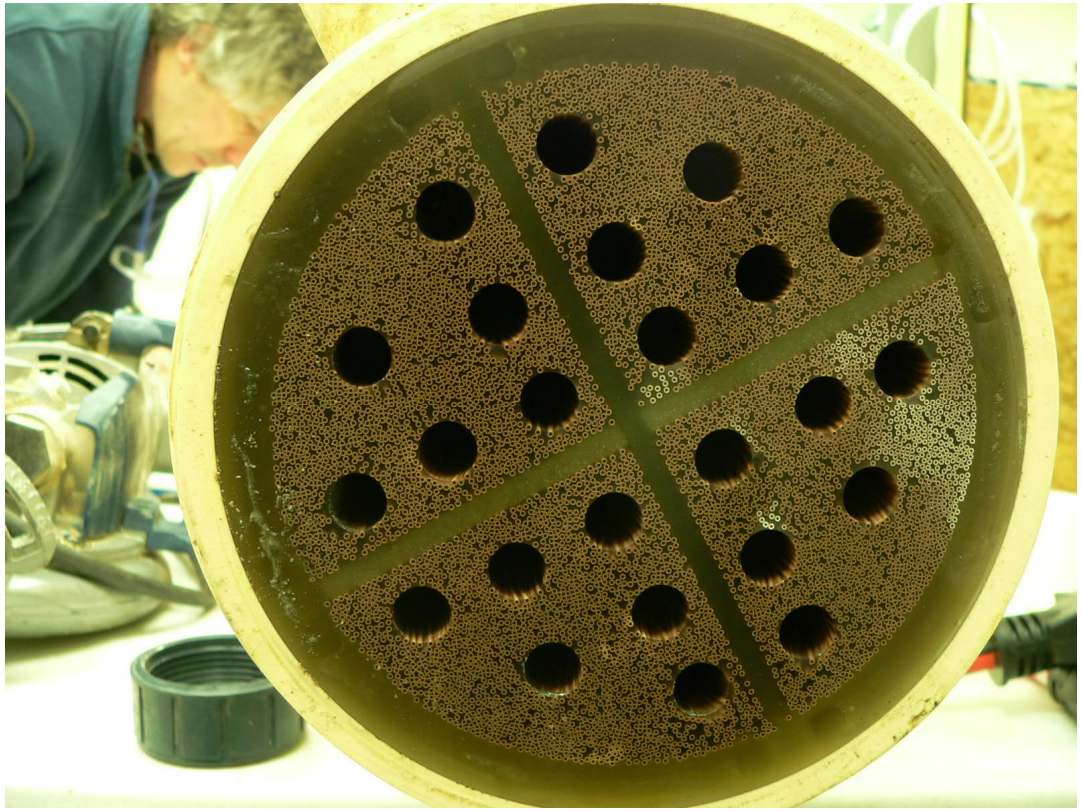
– It provides hints to improve influent pretreatment and cleaning regime

– Autopsy could identify how membranes are compromised

General Autopsy Procedure

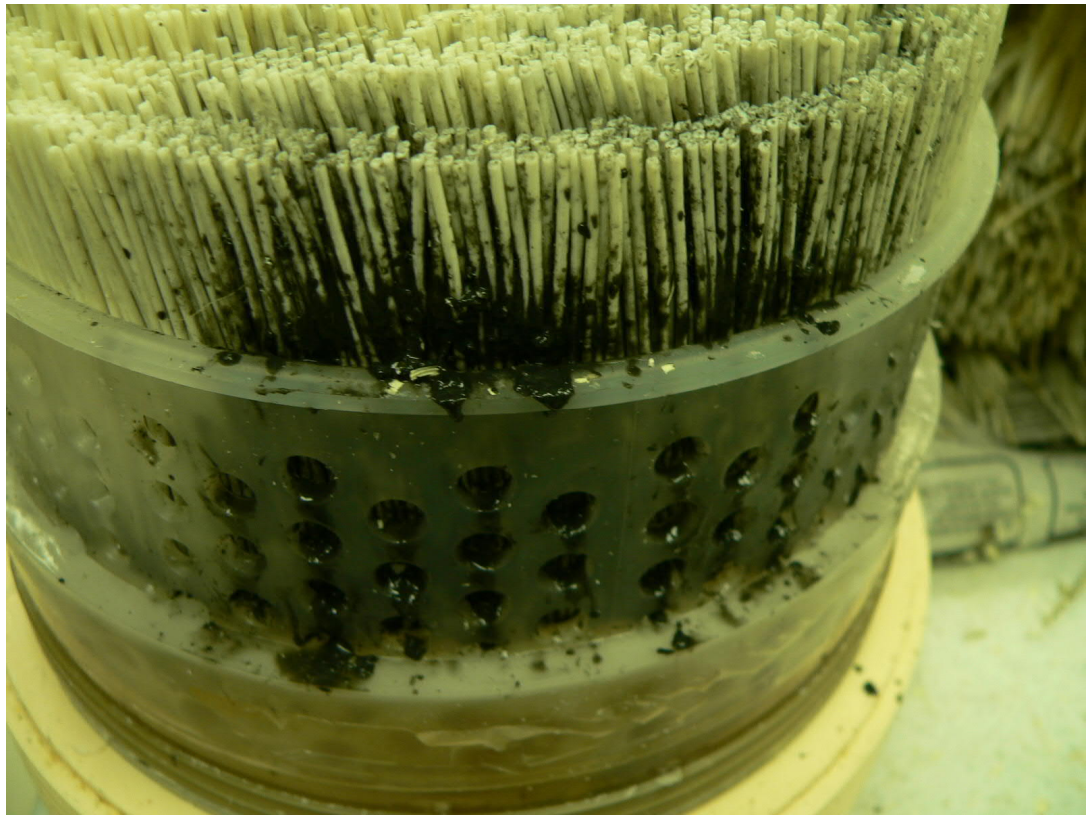
- Membrane module selection (pick the ones that are leaking and representative)
- Physical inspection
- Module dissection
- Microscopy analysis
- Fouling material analysis
- Membrane fiber physical strength test
- Cleaning efficacy study
- Data interpretation and recommendation

Membrane Inspection & Opening the Module



Membrane Inspection

– Sludge accumulate around the perimeter, indicating unbalanced and insufficient hydraulic backwash design



Physical Damage on Membrane Surface

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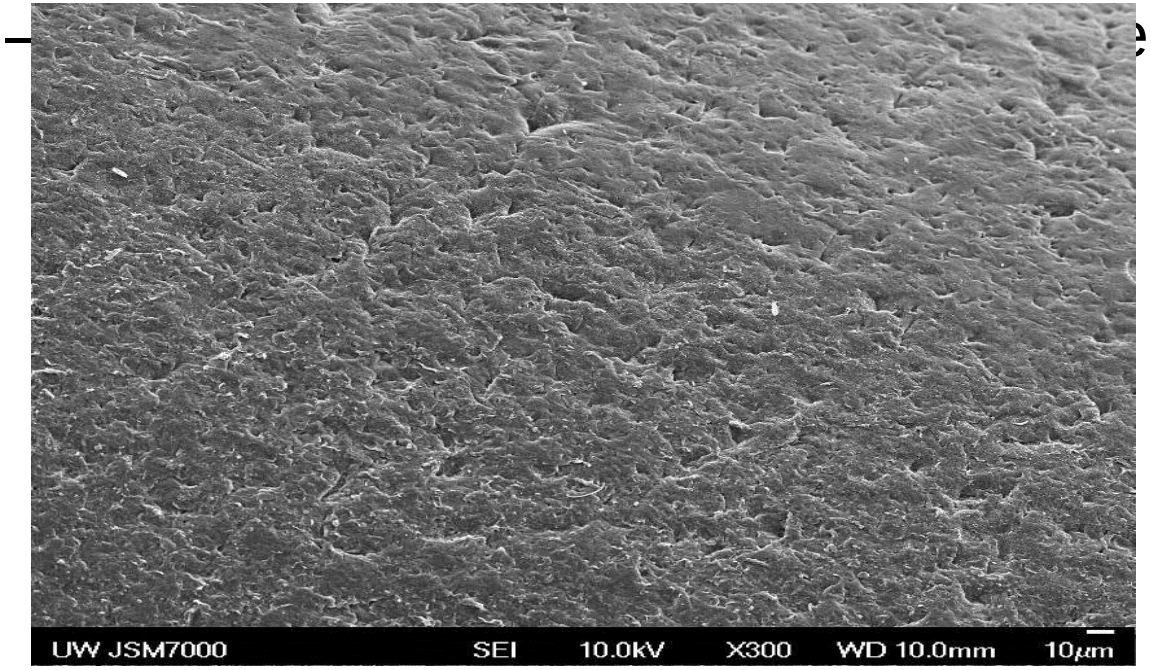
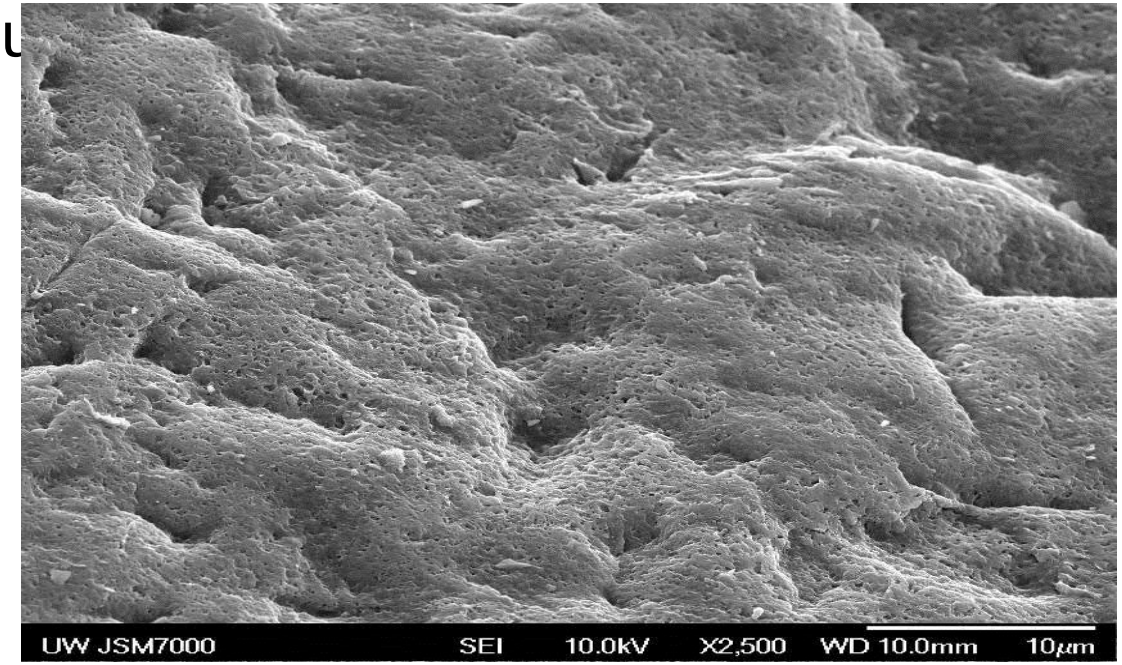
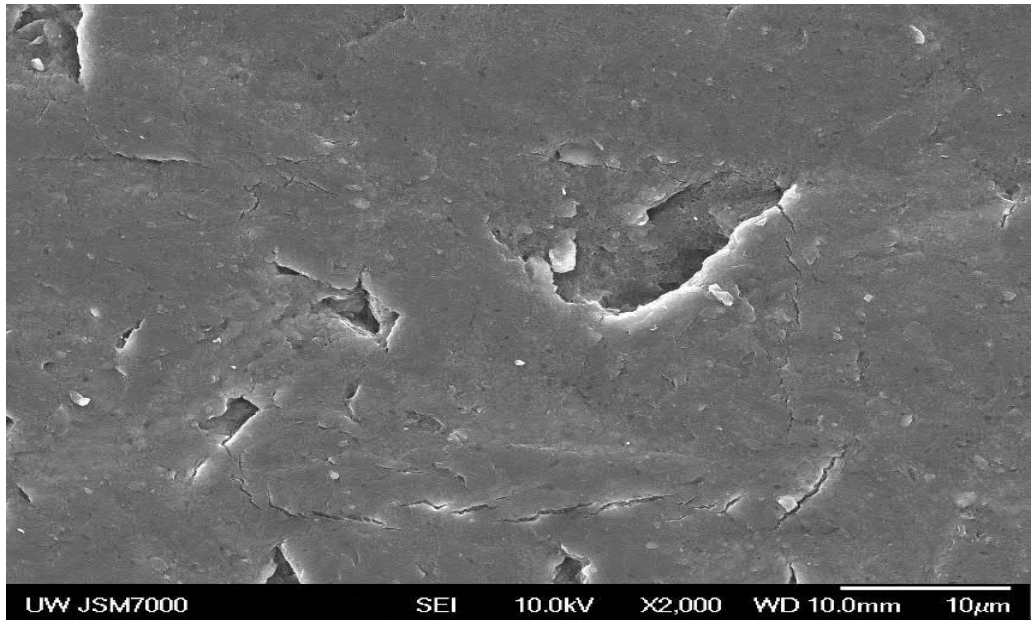


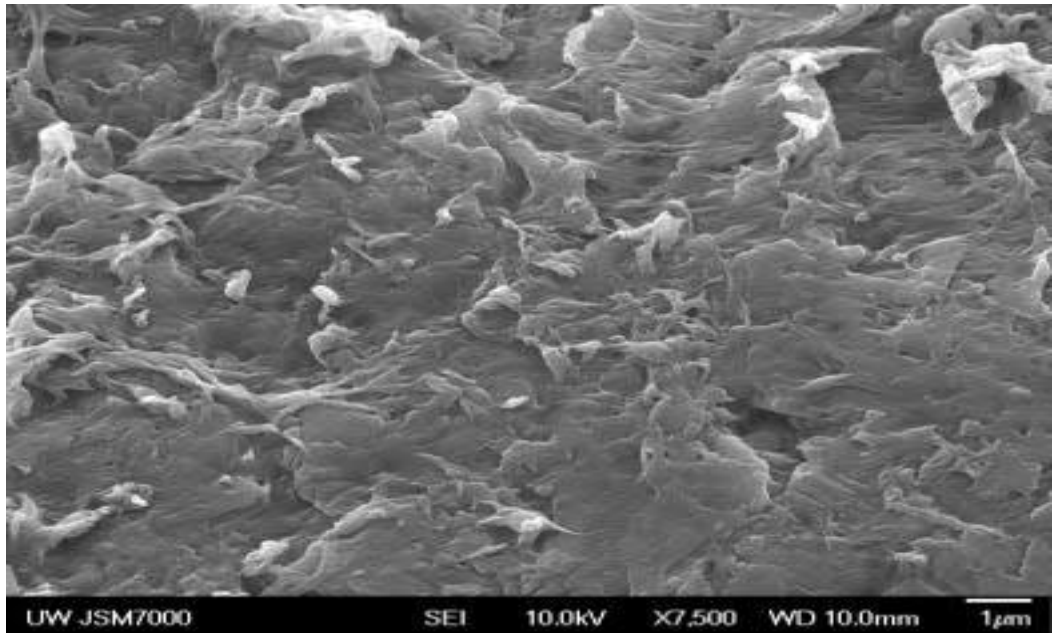


Chemical Damage to Membrane Surface

– Serious membrane surface damage due to aggressive chemical cleaning
  - Strength of cleaning chemical could be too high
  - Too many and frequent extensive CIP

– Chemical damage to membranes could lead to reduced permeability and weaken mechanical strength of membrane fiber



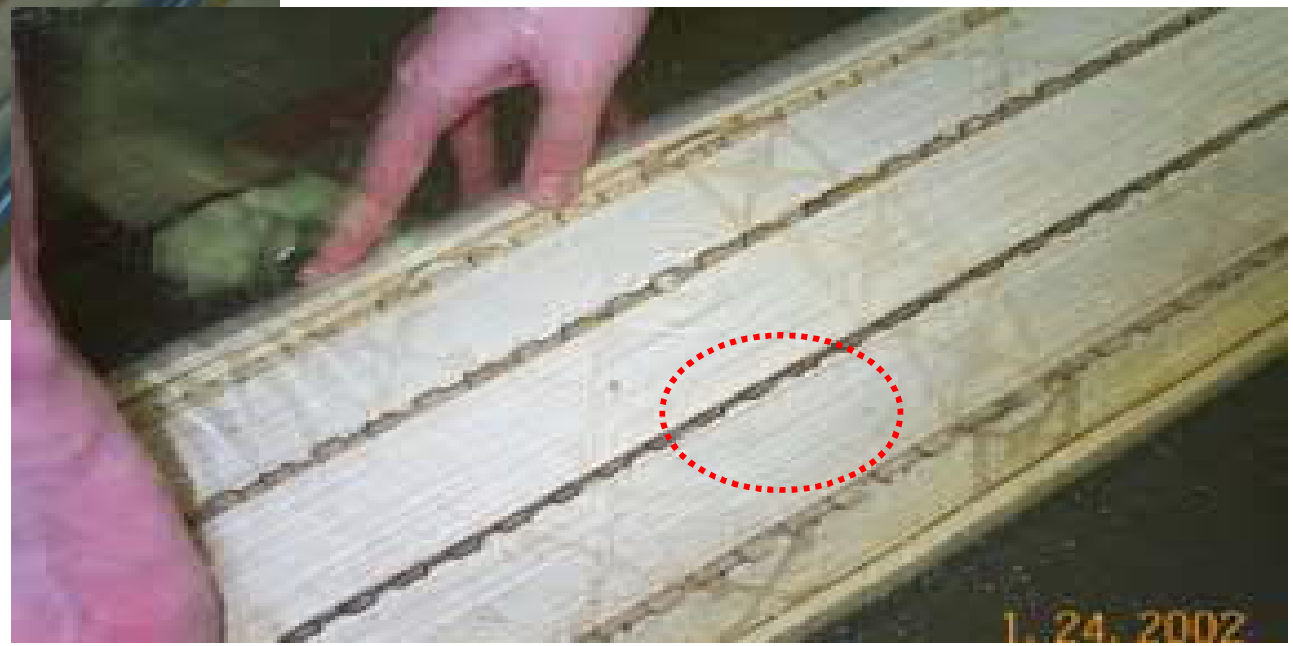


Module Integrity Inspection

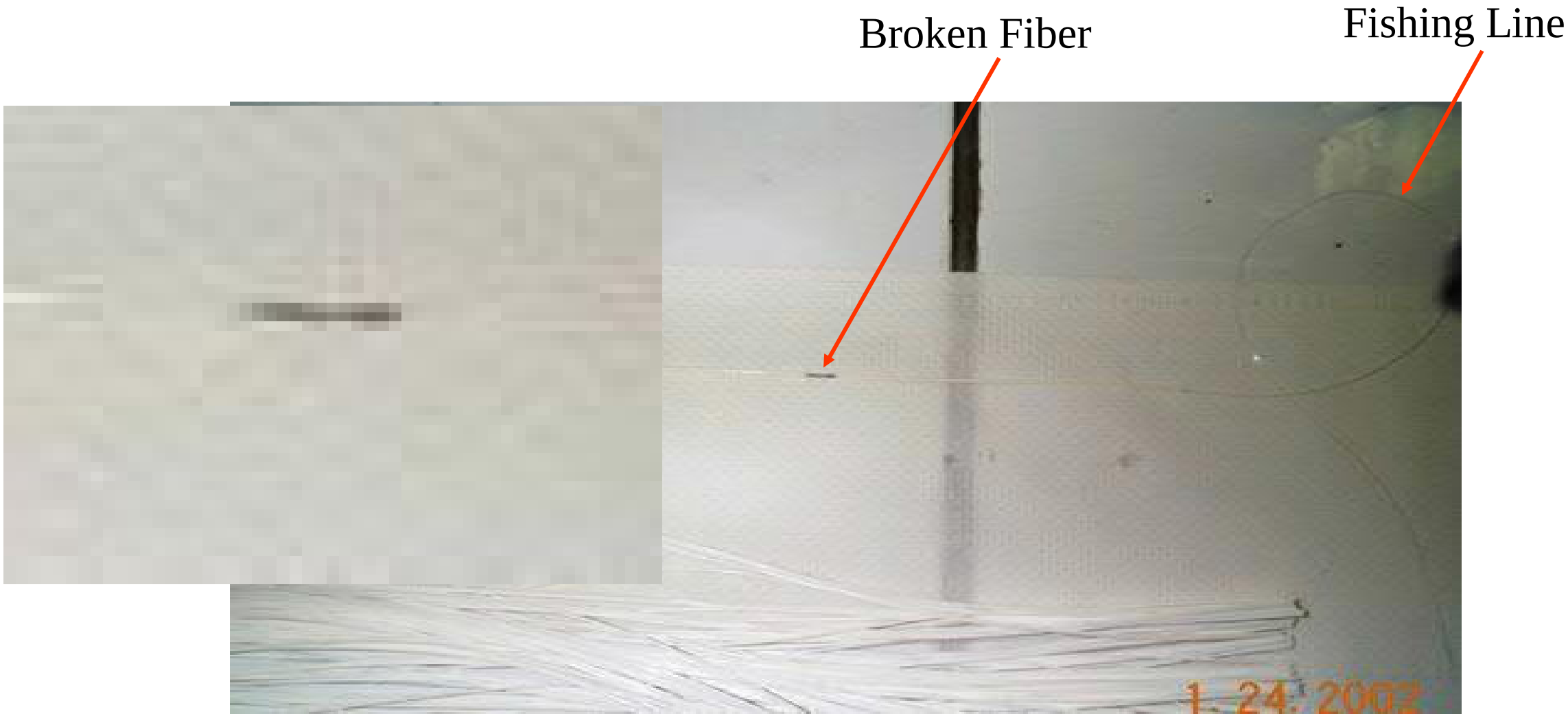
– A fishing line was used to mark the broken fiber

Membrane Module Dissection

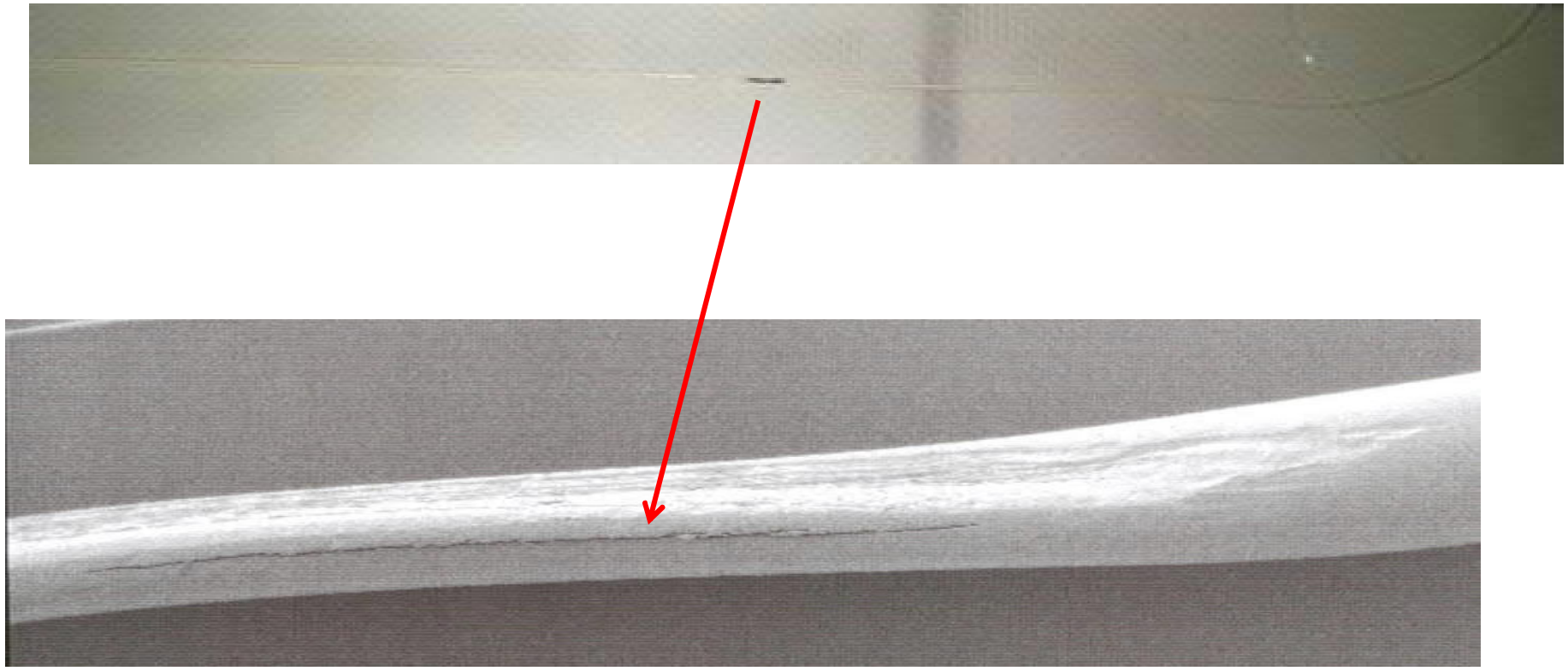
Locate Broken Fiber



Identify Broken Fiber



Broken Membrane Fiber



Membrane Autopsy with Microscopic Analysis

- Light scattering microscope
- Scanning electron microscope (SEM)
- Environmental SEM (ESEM)
- Field emission SEM (FESEM)

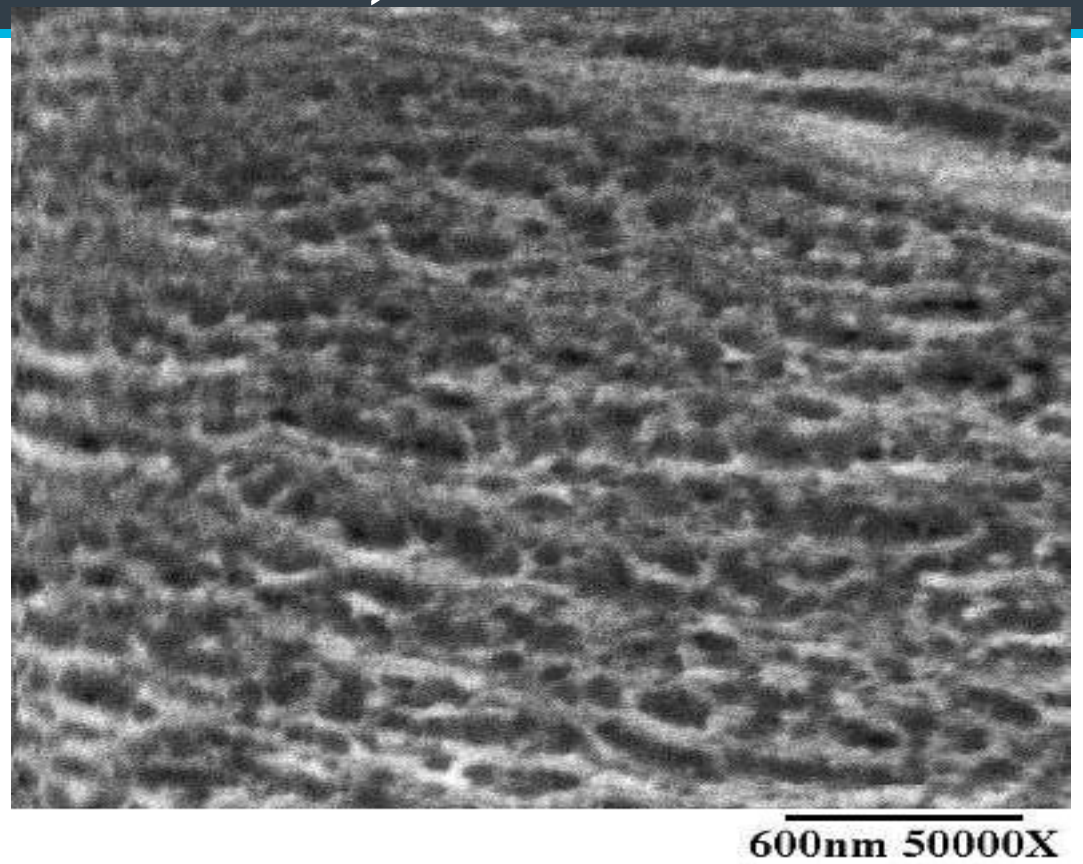
Light Reflective Microscope

New Membranes

- No sample preparation; no distortion
- Color image (3 - 100 X)

Field Emission SEM (FESEM)

New Membrane Surface



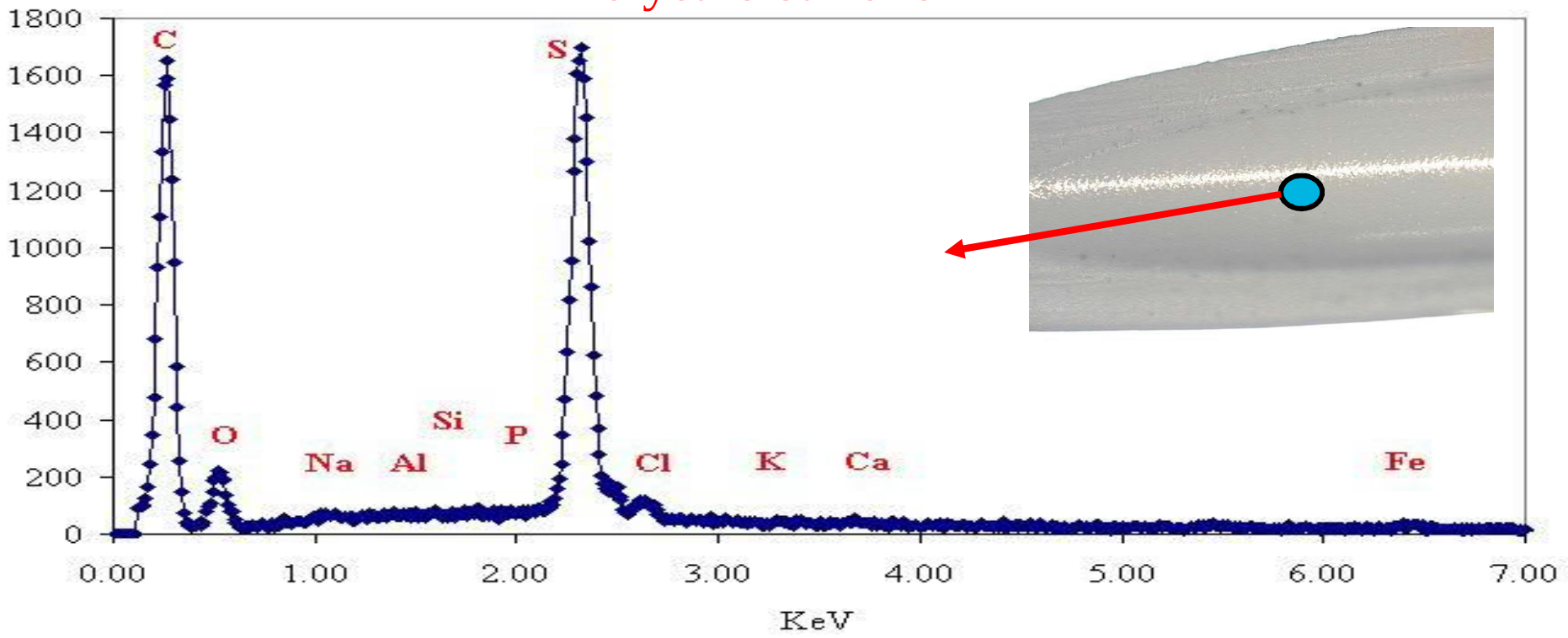
Pore Structure

Very high magnification for detail structure

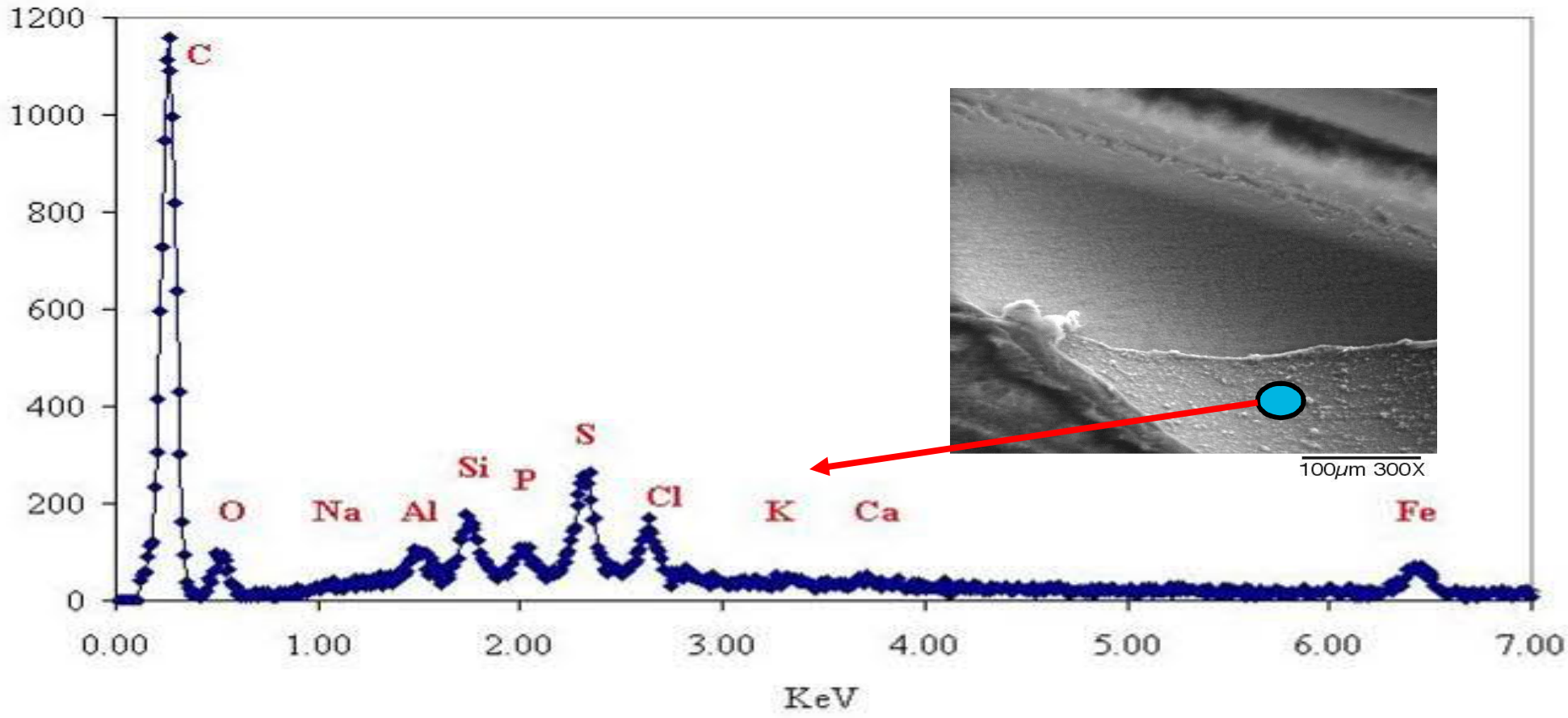
Electron Dispersion Spectrum (EDS)

Perform elemental analysis, excellent for inorganic compound

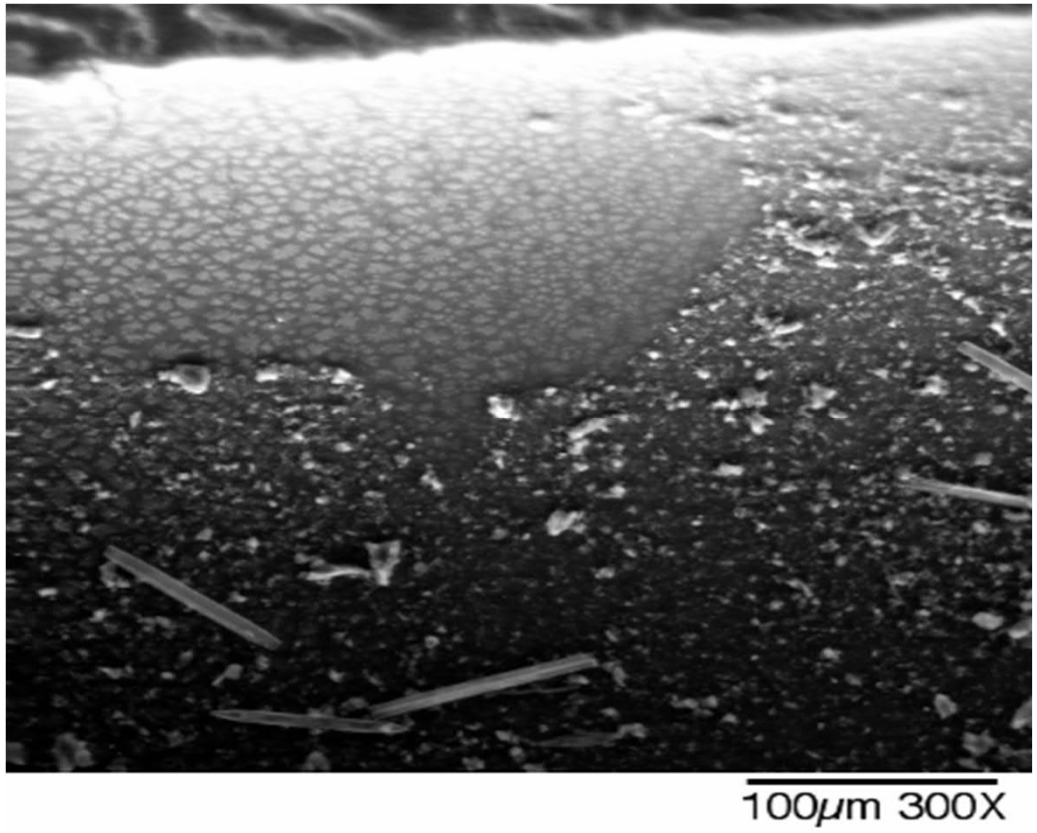
Polyethersulfone

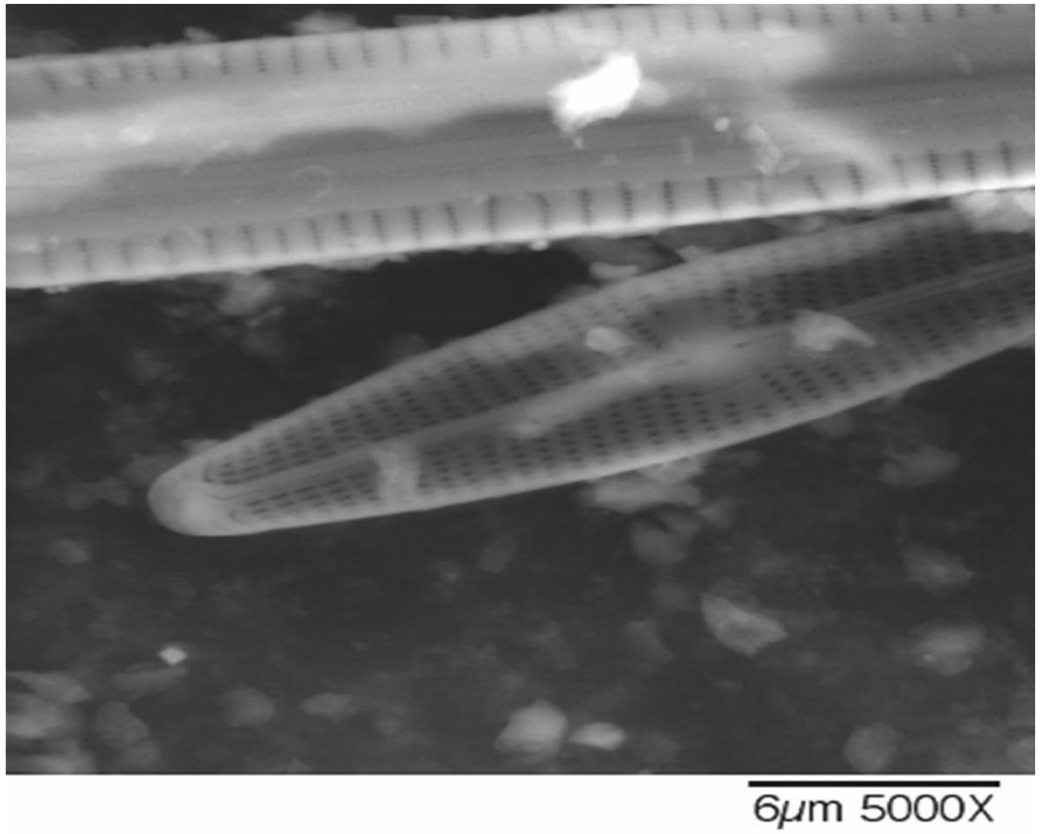


EDS on Delaminated Film



Environmental Scanning Electron Microscope (ESEM)

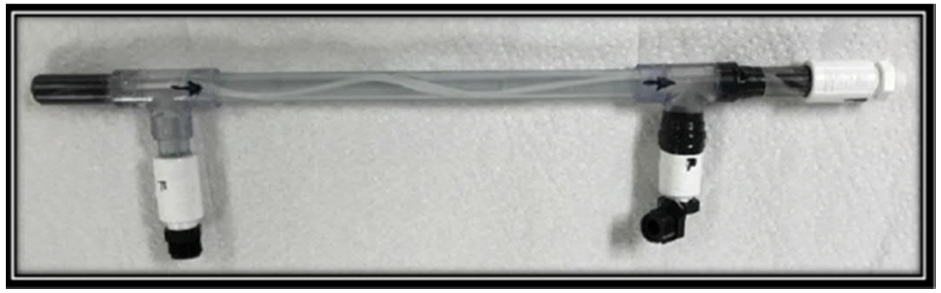




- No sample preparation; no distortion
- High magnification

Advanced Membrane Testing & Research

- Mini Module Testing
- Chromatic Elemental Imaging (CEI)



Mini-module Testing Equipment

Features

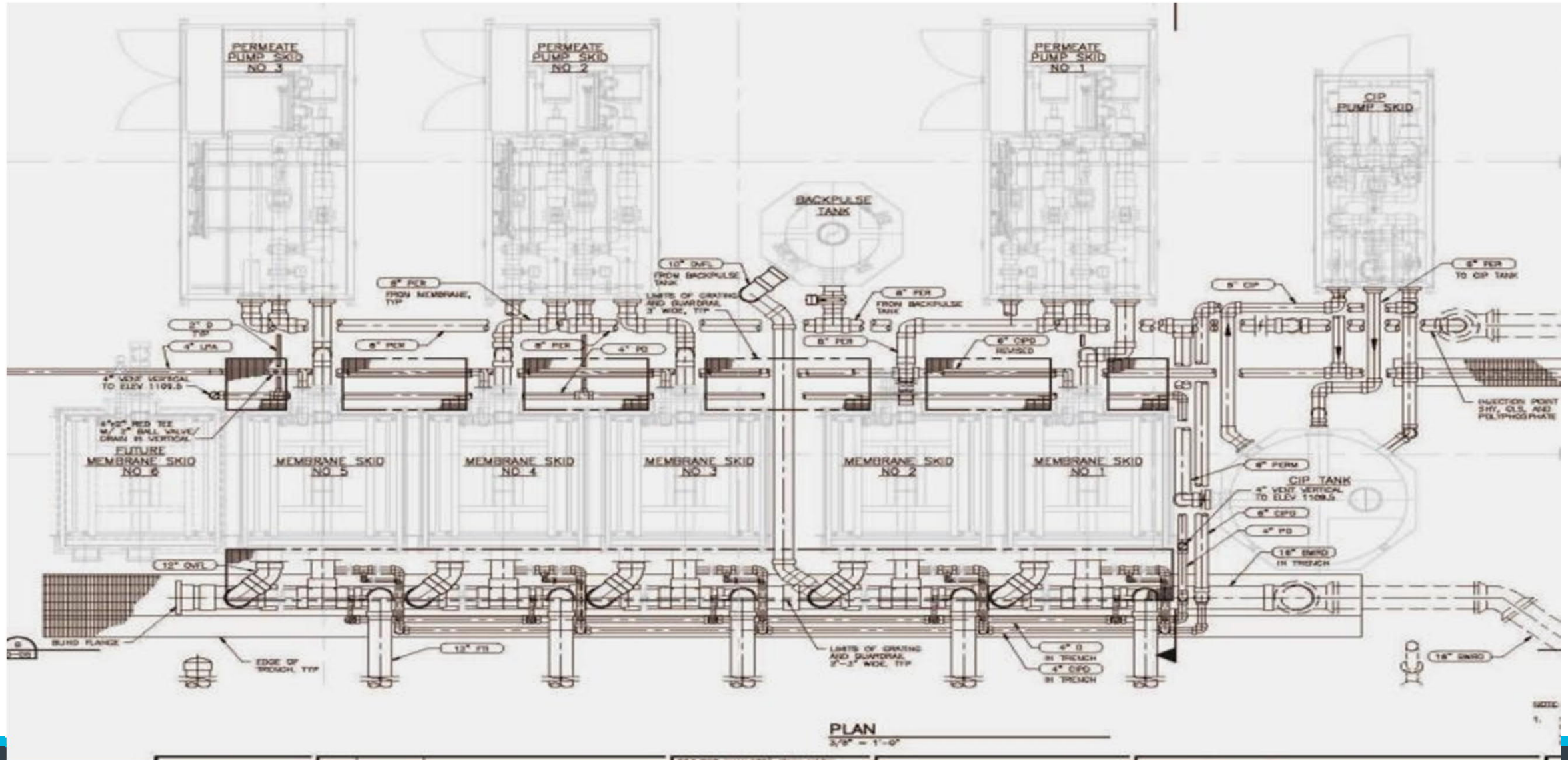
- Computer integrated
- Backwash
- CEBs
- ECEB

- Complete simulation
- Re-pot used fibers into mini-module
- Optimize chemical cleaning approach

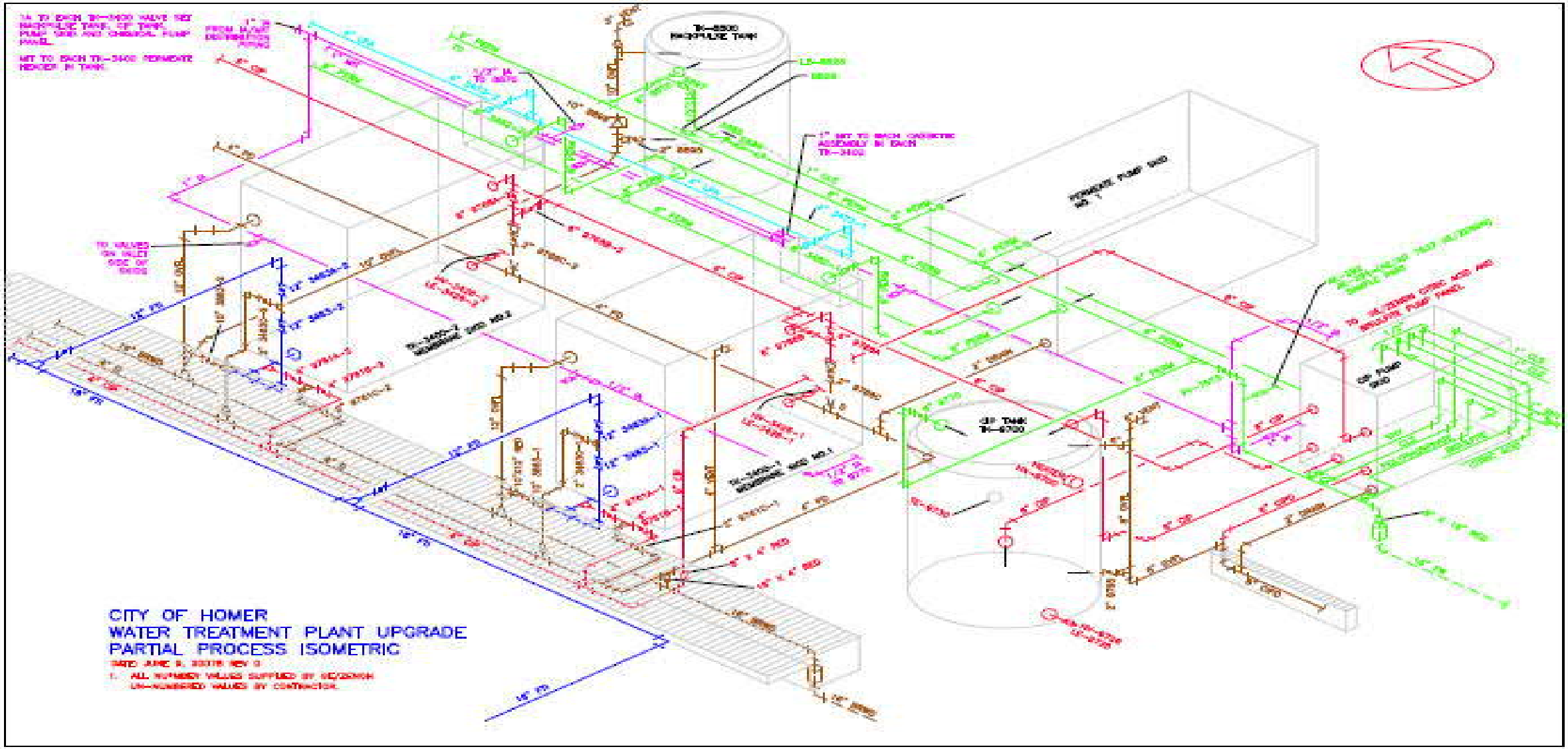
Membrane Process Design Considerations

- Make sure adequate membrane surface area is acquired to provide firm capacity regardless of water temperature
- Adequate safety factors should be included to account for membrane aging issues
- Monitor membrane permeability rather than TMP
- Adequate pretreatment should be included to accommodate potential raw water quality changes
- Overall plant hydraulics and flow balance should be evaluated: constant flow or constant flux

Piping Looks Relatively Simple - Sure



Piping Isometric Constructed From P&ID's and Vendor's Various Shop Drawings



Approved Shop Drawing Could be Changed

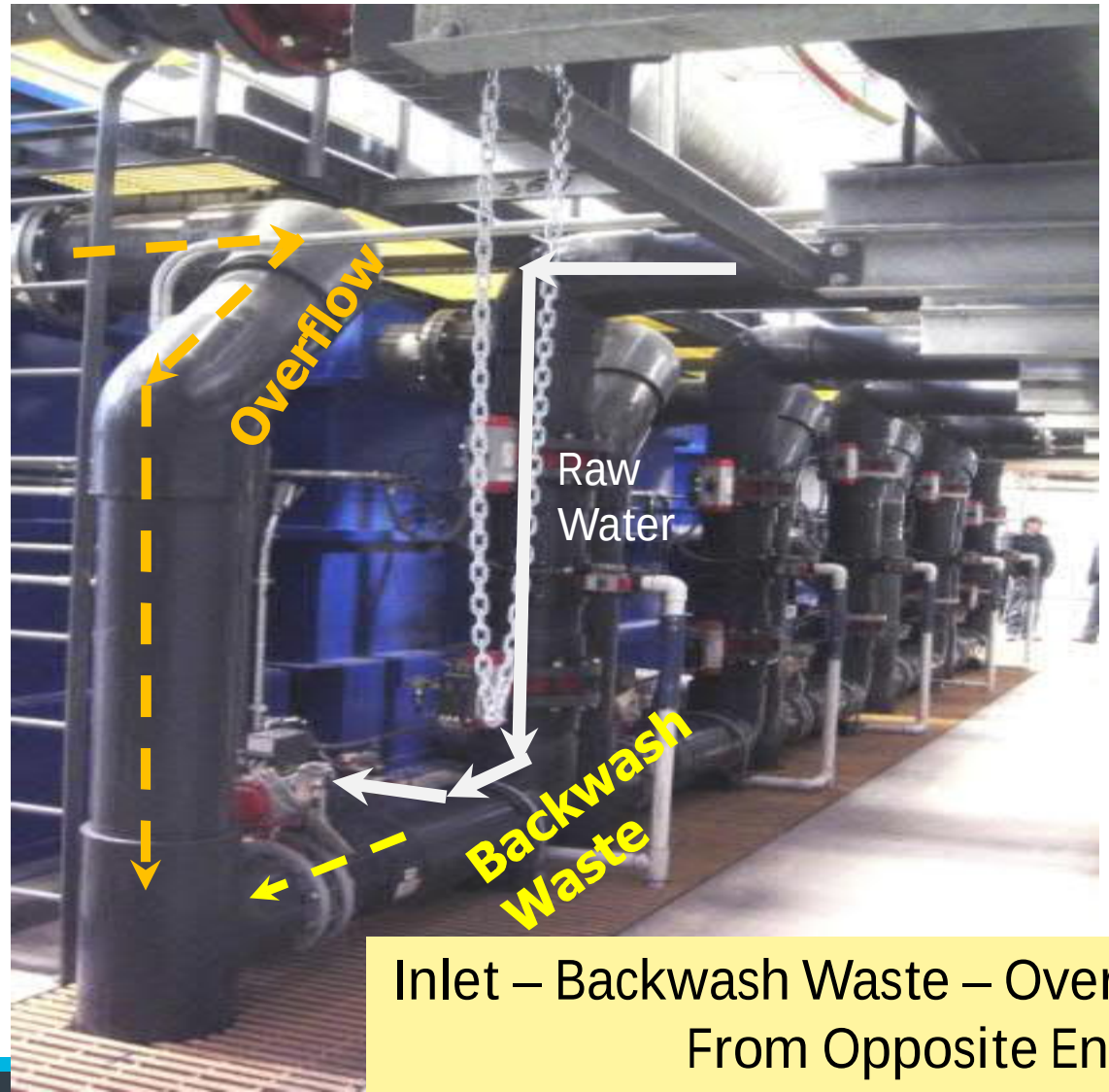
Permeate – Backwash – CIP Supply Piping to Pump Skids

Seismic Design Should be Included

Ventilation should be considered for Chemical Cleaning

Planning For Startup Begins In Design

Easy Puzzle to Put Together?
Installation Manuals Up to Date and Clear?



Inlet – Backwash Waste – Overflow – CIP Return – CIP Drain Piping
From Opposite Ends of Inlet Side of Tanks