Troubleshooting of FILMTEC™ Membrane Plants

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Water & Process Solutions

Troubleshooting

means:

identify & correct performance issues

- ✓ **Analyze symptoms**
- ✓ **Identify and localize causes**
- ✓ **Corrective measures**
- ✓ **Preventive measures**

Troubleshooting in RO und NF Plants

Contents

1. **Symptoms and causes**
2. **Effect on membrane performance if something goes wrong**
3. **Problem area: Feed water / pretreatment**
4. **Problem area: Plant operation**
5. **Problem area: System components**
6. **Troubleshooting Summary**

Symptoms and Causes

Performance problems are recognized only when the symptoms are significant:

- **Loss of normalized permeate flow rate**
- **Increase in normalized salt passage**
- **Increase in pressure drop**

Symptoms and Causes

Performance problems are recognized only when the symptoms are significant:

- **Loss of normalized permeate flow rate**
  - **Sudden or gradual change?**
  - **First or second stage?**
  - **Cleaning experience?**

Symptoms and Causes

Performance problems are recognized only when the symptoms are significant:

- **Loss of normalized permeate flow rate**
- **Increase in normalized salt passage**
  - **Sudden or gradual?**
  - **First or second stage?**
  - **Uniform or specific vessels?**
  - **Probing!**

Symptoms and Causes

Performance problems are recognized only when the symptoms are significant:

- **Loss of normalized permeate flow rate**
- **Increase in normalized salt passage**
- **Increase in pressure drop**
  - **First or second stage?**

Symptoms and Causes

Early detection of potential problems requires:

- **Instruments, sensors**
- **Calibration of instruments**
- **Record keeping**
- **Data normalization:**

  Translation of measured performance under prevailing conditions into performance under reference conditions

Symptoms and Causes

Direct causes of performance problems:

- **Fouling/Scaling**
  - Flux loss, salt passage increase, differential pressure increase
- **Mechanical damage**
  - Salt passage increase, differential pressure increase
- **Chemical damage**
  - Salt passage increase, Flux increase

Troubleshooting in RO und NF Plants

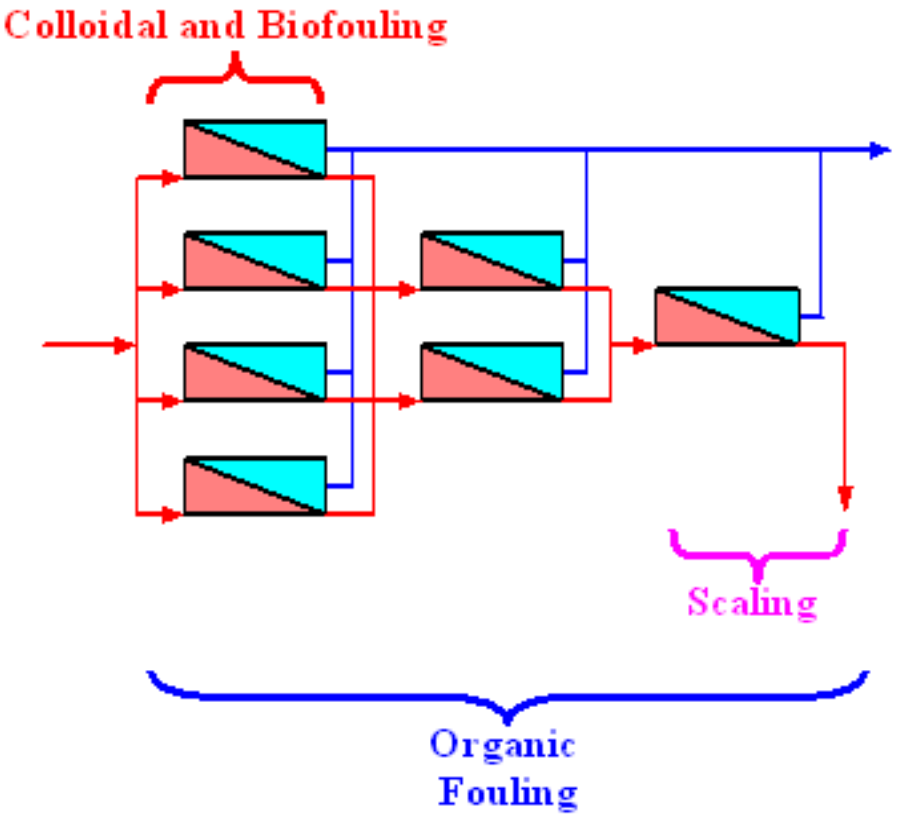
Contents

Effect on membrane performance if something goes wrong

- **Fouling / Scaling**
- **Mechanical damages**
- **Chemical damages**

Fouling/Scaling

Fouling often originates in a specific part of the RO/NF svstem:



Fouling/Scaling

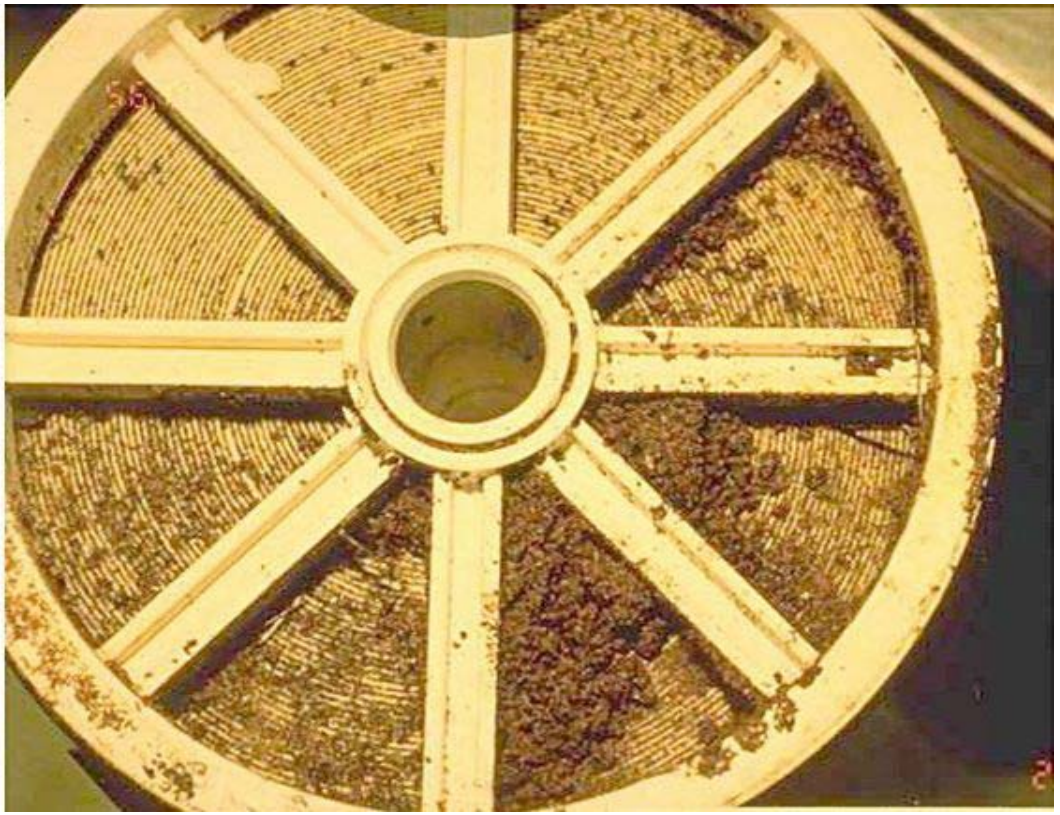
commonly caused by raw water characteristics and inappropriate pretreatment

Fouling

Colloidal and particle fouling

caused by solids from the pretreatment entering the first stage elements

Colloidal and particle fouling



Extreme cases of fouling

Fouling

Colloidal and particle fouling

caused by solids from the pretreatment entering the first stage elements

Correction:	Alkaline/detergent cleaning, acid cleaning
Prevention:	Pretreatment improvement Membranes with wider feed spacer

Pretreatment methods to control particle fouling

- Filtration
  - Sand filter
  - Multimedia filter
  - Ultrafiltration
- Coagulation – filtration
- Coagulation/flocculation – filtration
- Coagulation/flocculation – clarification – filtration

Fouling

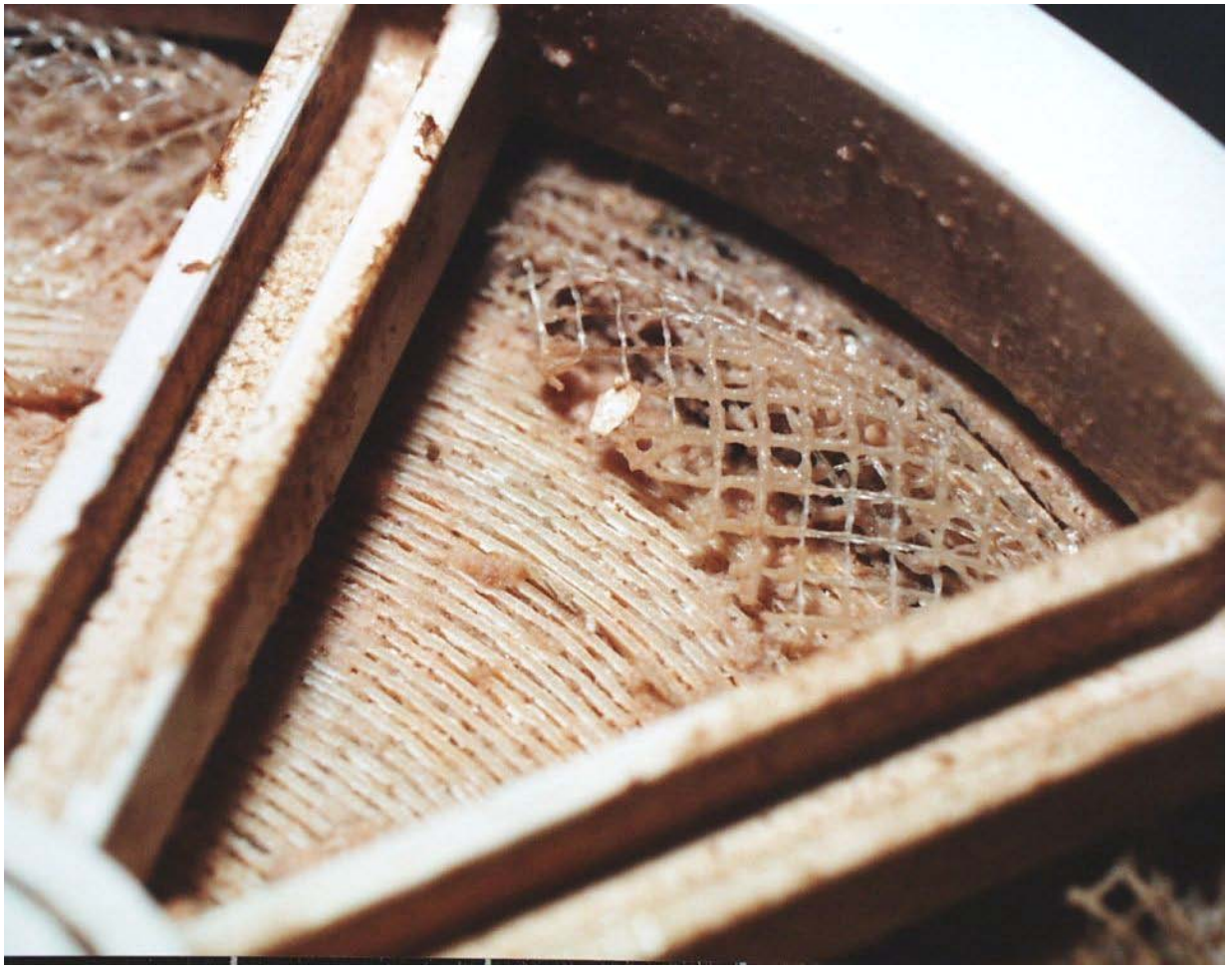
Biofouling

Occurs due to

- High biogrowth potential in feed water
- Improper operation and procedures
- Dead legs in system

typical: ΔP increase of front end elements

Biofouling



Fouling

Biofouling

Occurs due to

- High biogrowth potential in feed water
- Improper operation and procedures
- Dead legs in system

typical: ΔP increase of front end elements

Correction:	Alkaline cleaning
Prevention:	Pretreatment improvement Fouling resistant membranes Regular cleaning and sanitization Sanitary design

Pretreatment methods to control biofouling

- Biofiltration
  - Slow sand filter
  - GAC filter
  - Pre-oxidation, e.g. by ozone
- Intermittent biocide dosage, e.g. DBNPA

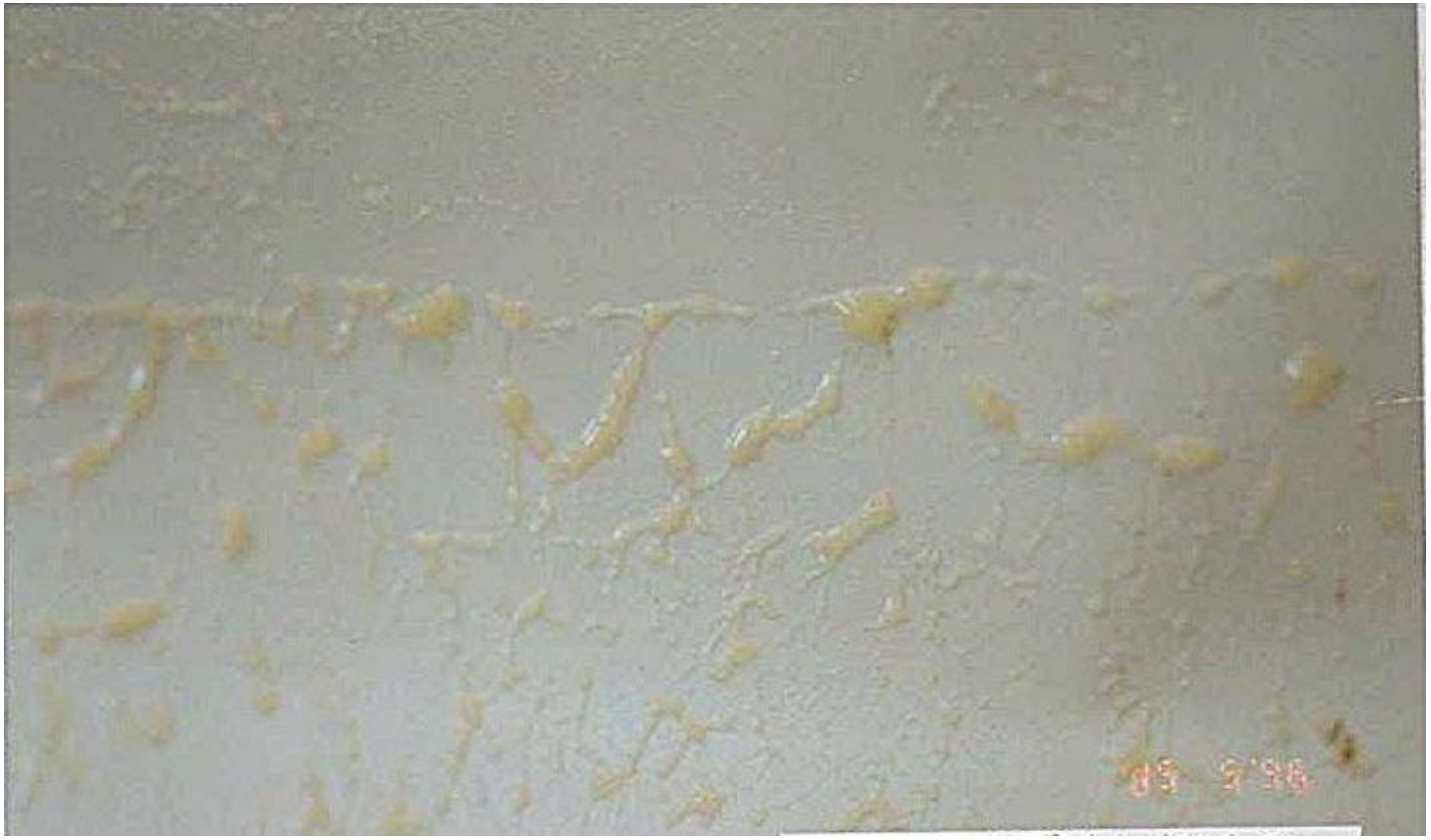
Fouling

Organic Fouling

from

- Natural organic matter in the feed water
  - NOM, humic substances
- Polluted raw water
  - Oil, grease
- Polyelectrolytes in flocculation/coagulation pre-treatment
  - Scaling inhibitors
  - Coagulants

Precipitated scaling inhibitor



Fouling

Organic Fouling

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  - NOM, humic substances
- Polluted raw water
  - Oil, grease
- Polyelectrolytes in flocculation/coagulation pre-treatment
  - Scaling inhibitors
  - Coagulants

Correction:	alkaline cleaning
Prevention:	pretreatment improvement, XFR membranes

Pretreatment methods to control organic fouling

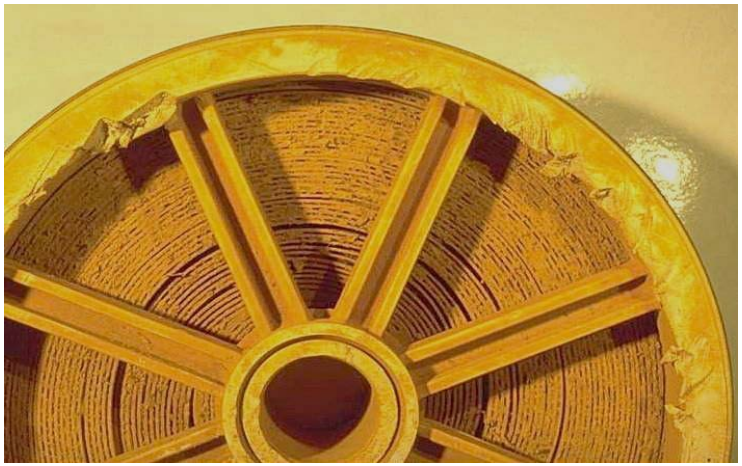
- Lime softening
- GAC filtration
- GAC biofiltration
- Scavenger
- Inline coagulation
- Coagulation/flocculation
- Coagulation/flocculation - clarification

Fouling

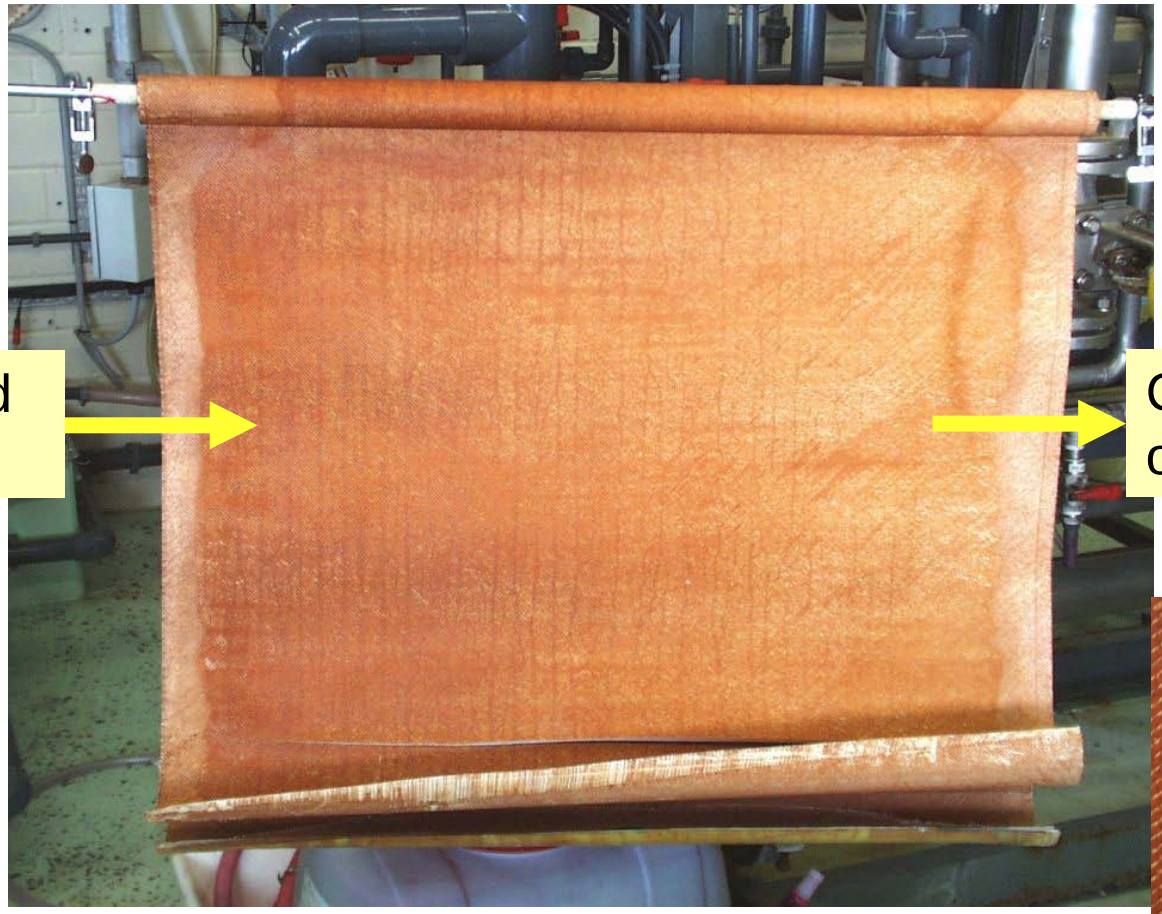
Metal oxide fouling

mainly occurs in the first stage

- from flocculation process
  - Iron
  - Aluminum
- from anoxic wells
  - Iron
  - Manganese
- from corroding system components
  - Iron
  - Copper



Iron fouling



Fouling

Metal oxide fouling

mainly occurs in the first stage

- from flocculation process
  - Iron
  - Aluminum
- from anoxic wells
  - Iron
  - Manganese
- from corroding system components
  - Iron
  - Copper

Correction:	Acid cleaning
Prevention:	Pretreatment improvement Corrosion resistant materials Membranes with wider feed spacer

Pretreatment methods to control metal oxide fouling

- Filtration
  - Sand filter
  - Multimedia filter
  - Ultrafiltration
- pH adjustment (Al^{3+})
- Anoxic process (Fe^{2+}/Mn^{2+})
- Oxidation – filtration (Fe^{2+}/Mn^{2+})

Fouling

Sulfur fouling

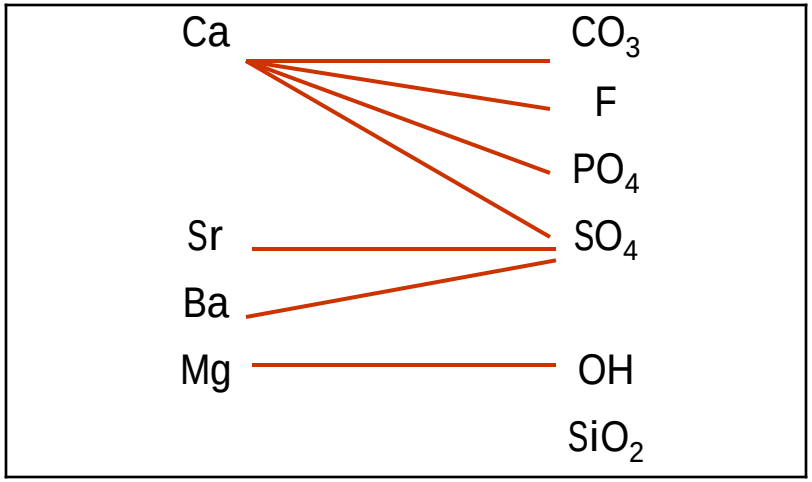
from

- Aeration or oxidation of hydrogen sulfide containing raw water
- Osmotic backflow of aerated permeate into a hydrogen sulfide containing anoxic system

Correction:	Membrane replacement
Prevention:	Avoid contact with air or oxidants

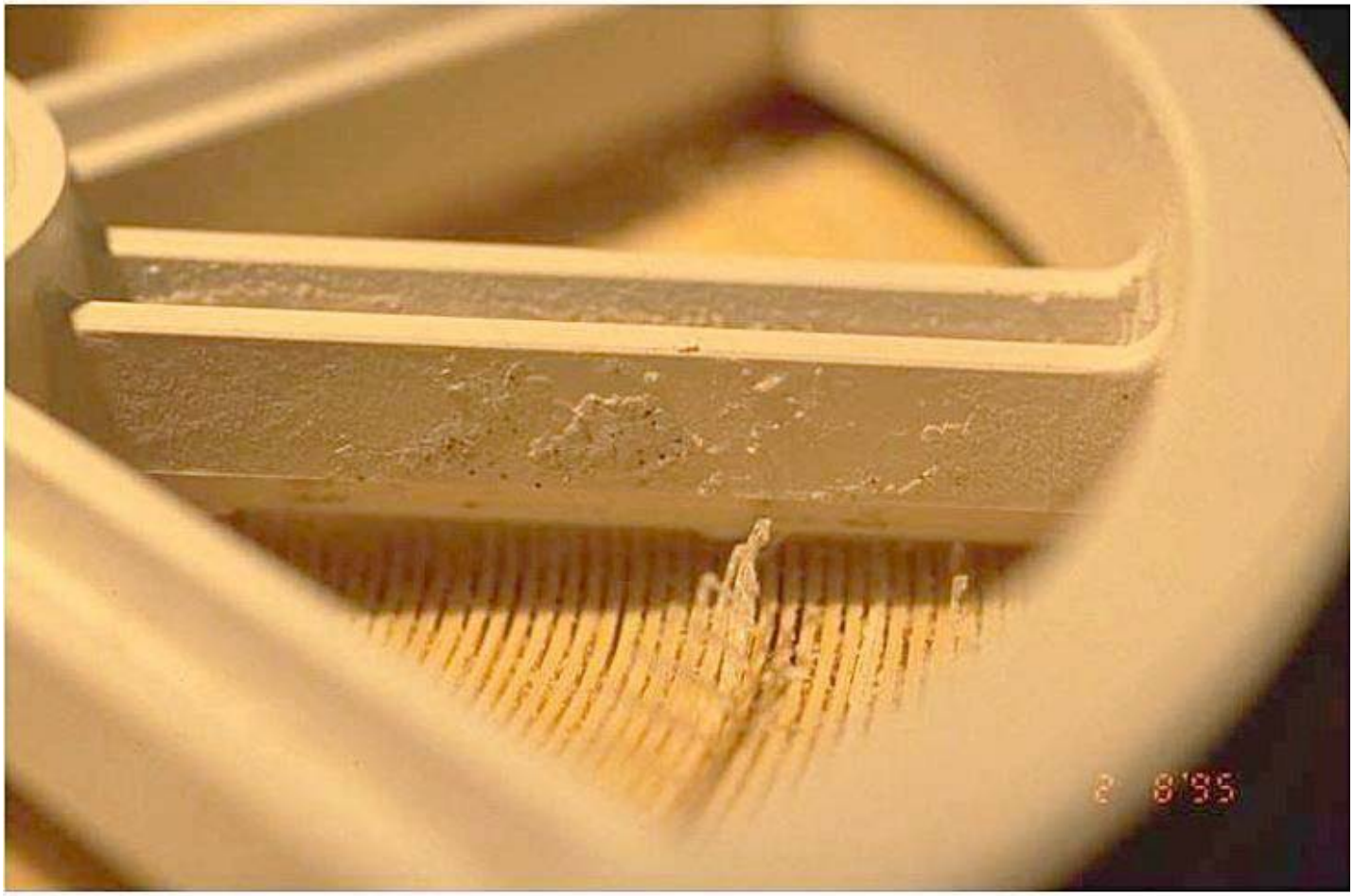
Scaling

Precipitation and deposition of sparingly soluble salts



- Starts in tail end of the system
- Caused by:
  - Raw water changes
  - Improper dosage of scaling inhibitor
  - Too high recovery

Scaling



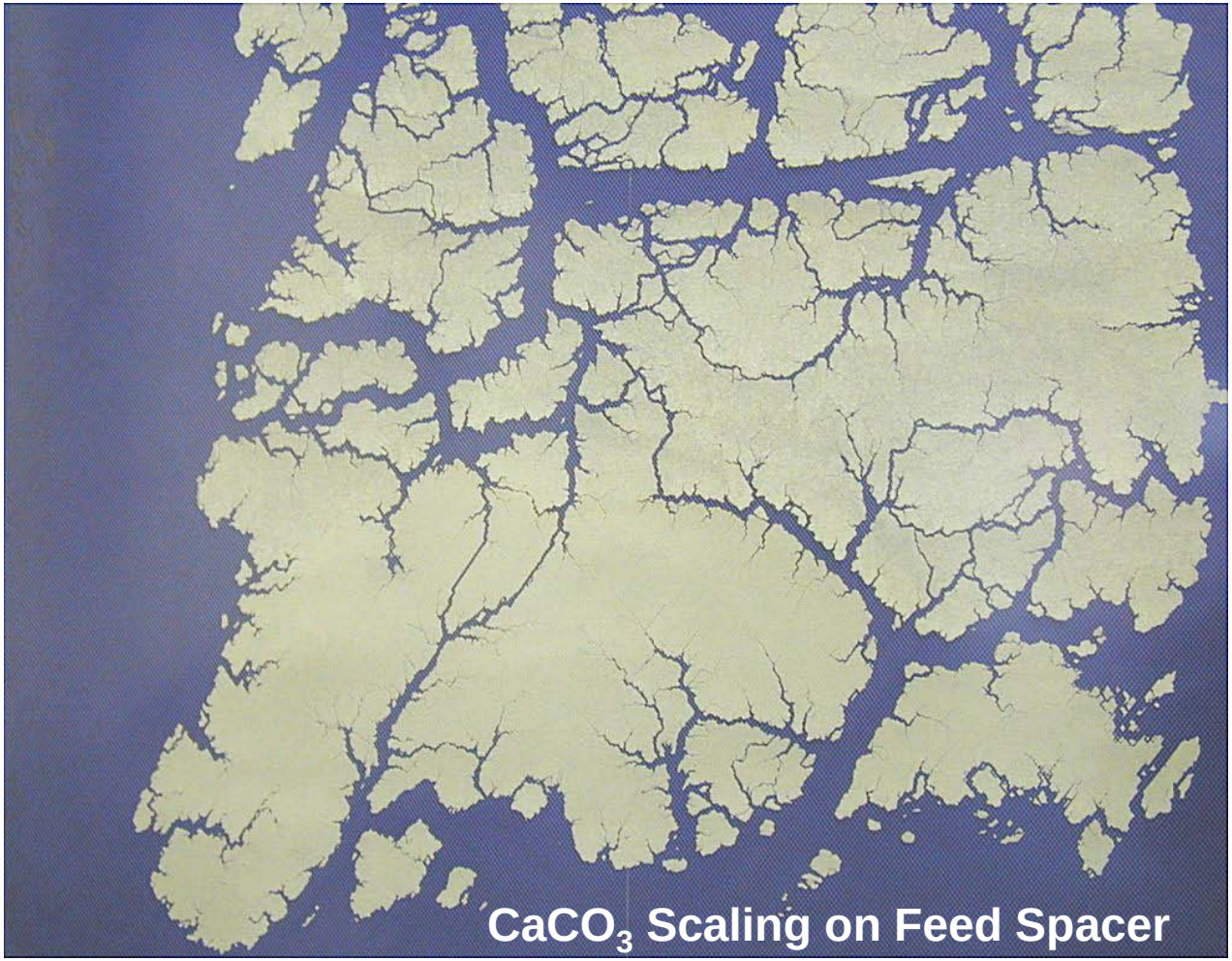
Extreme case of $CaCO_3$ scaling, concentrate side

Calcium carbonate scaling

Correction: Acid cleaning; extended acid contact time

Prevention: Pretreatment improvement

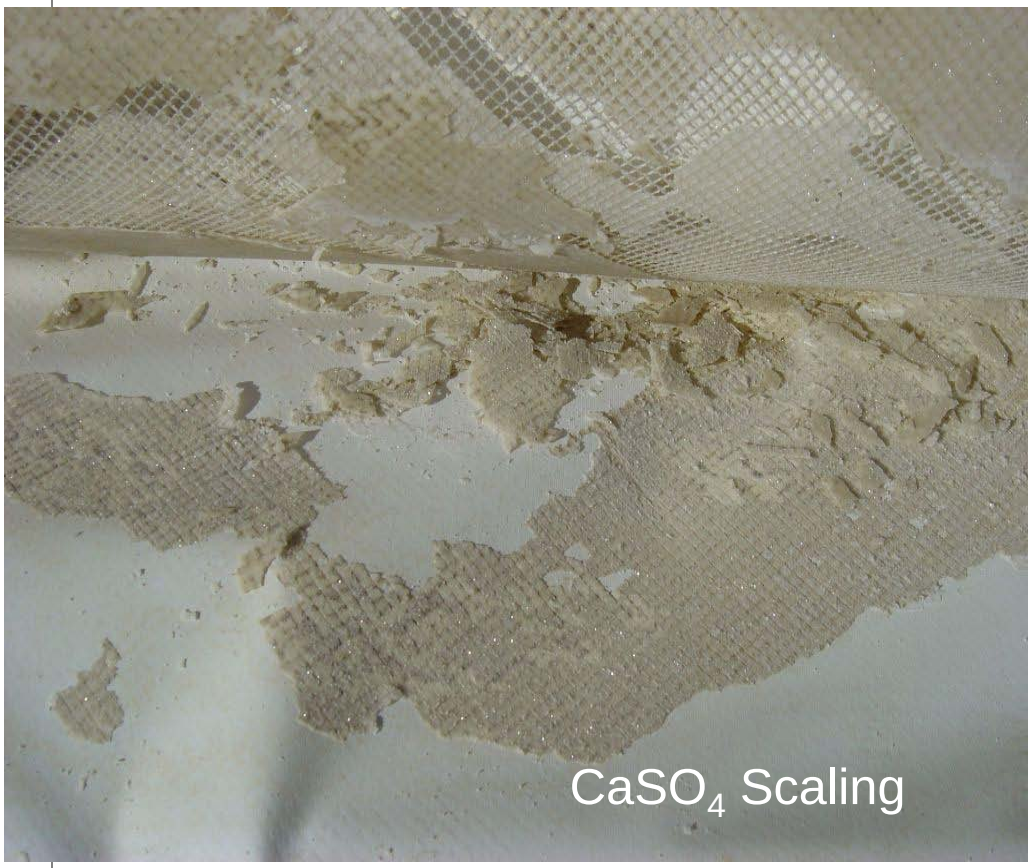
Scaling



Scaling

$CaCO_3$ Scaling on Feed Spacer

Sulfate scaling



Correction:	high pH EDTA cleaning (difficult!)
Prevention:	pretreatment improvement
	recovery reduction

Pretreatment methods to control scaling

- Acid addition (Carbonate)
- Antiscalant
- Softening (strong cation resin)
- Dealkalization (weak cation resin)
- Lime softening

Effect on membrane performance if something goes wrong

- Fouling / Scaling
- **Mechanical damages**
- Chemical damages

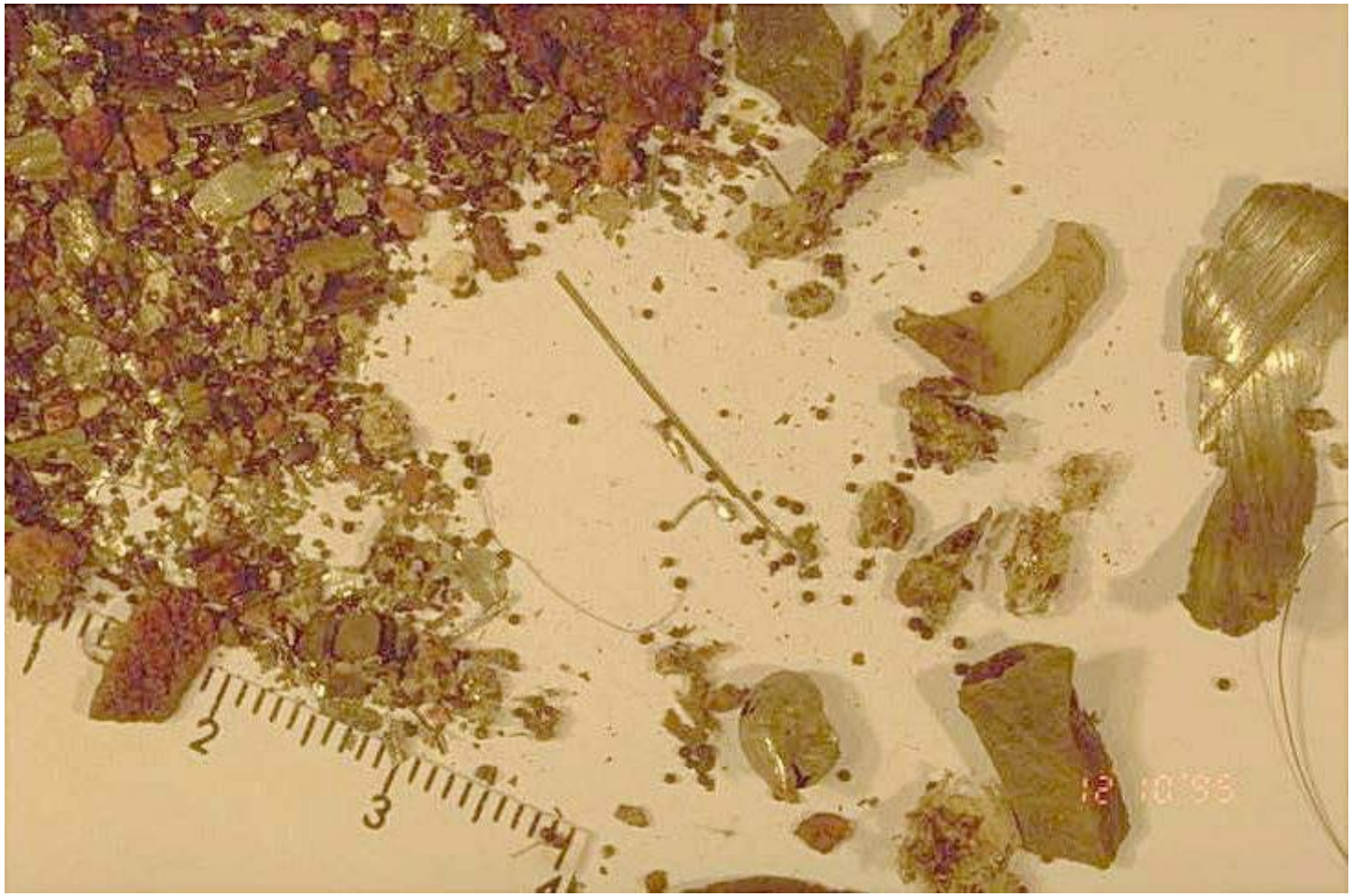
Mechanical Damages

Abrasion

Increased salt passage

- Membrane scratched by crystalline or sharp-edged solids in the feed water
- Lead elements mostly affected

Abrasion by sharp-edged particles

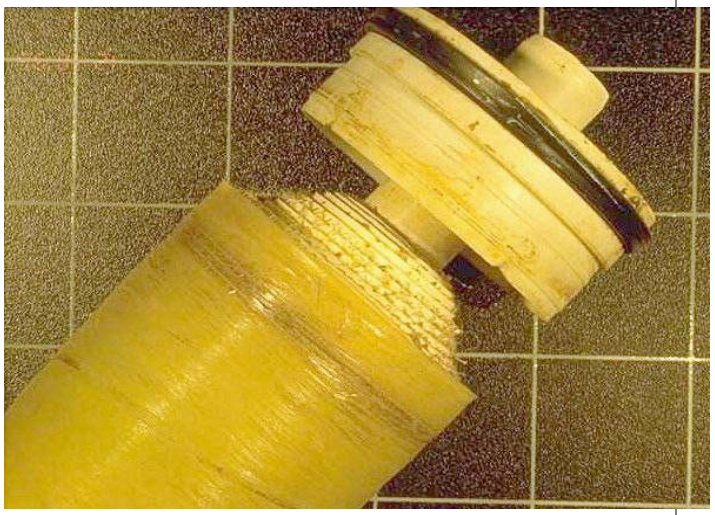


Mechanical Damages

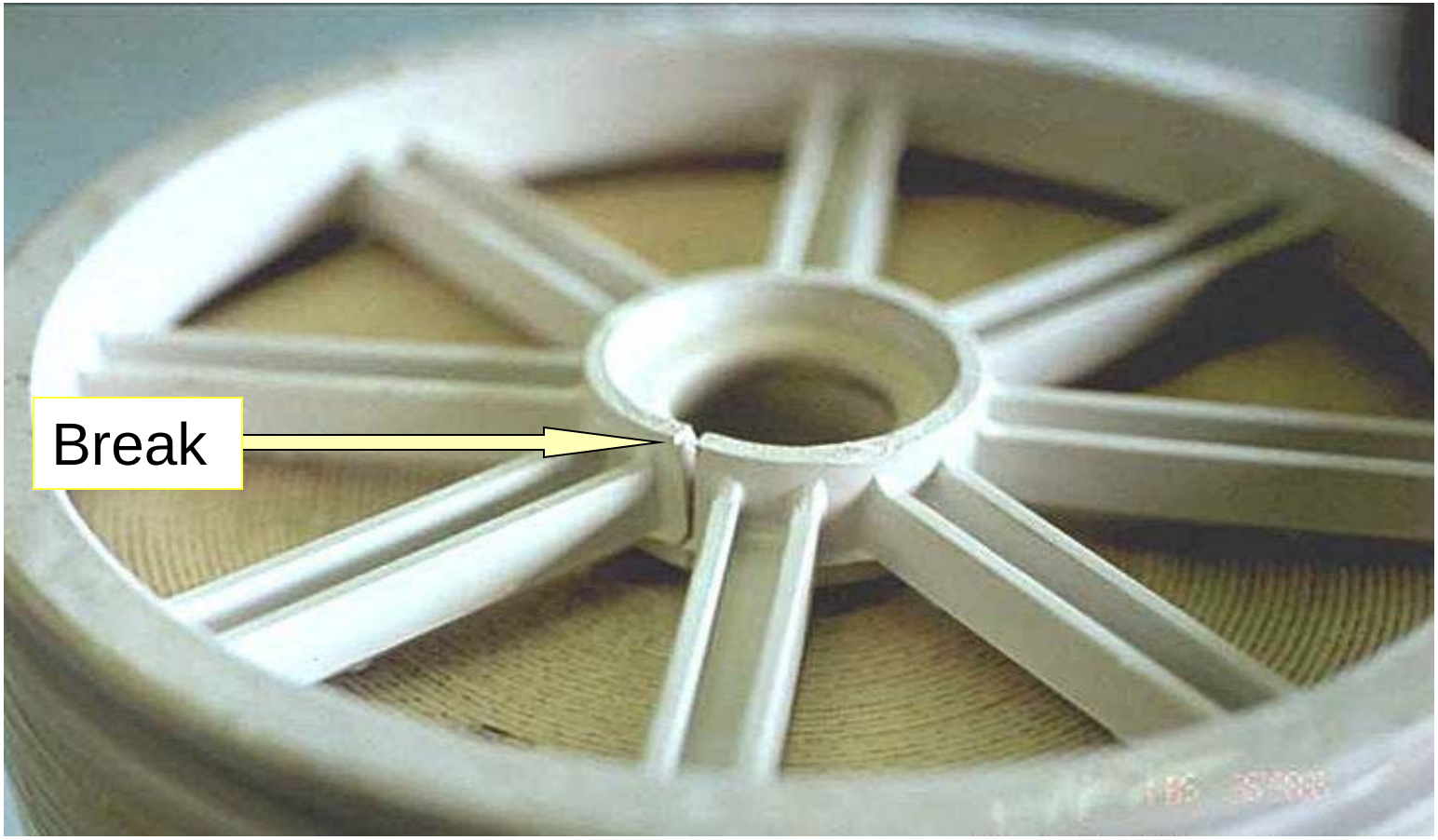
Telescoping

Axial displacement of the scroll by high pressure differential feed-concentrate caused by

- Water hammer
- High feed flow rate
- Feed channel plugging
- Missing thrust rings



Telescoping



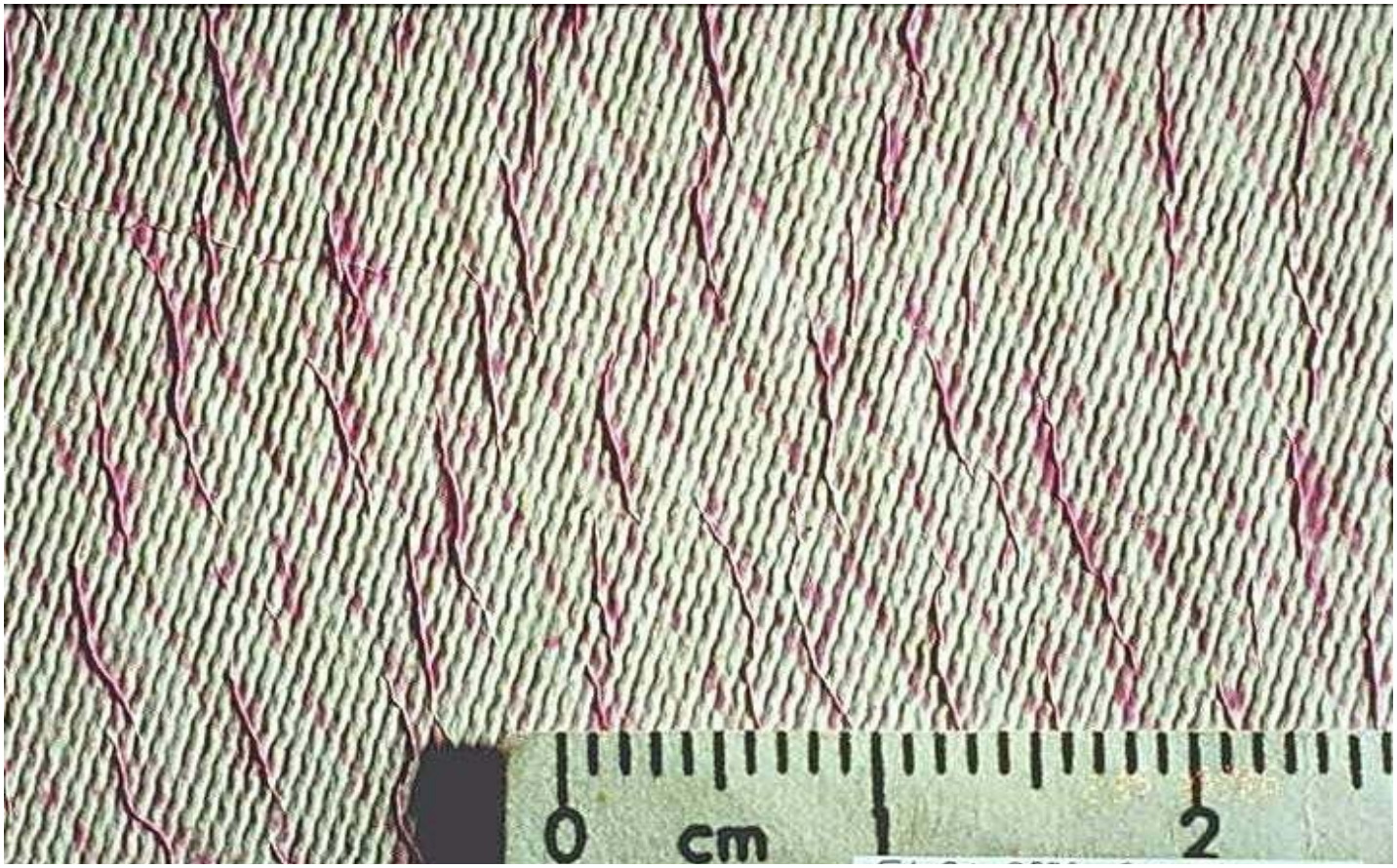
Mechanical Damages

Intrusion of the membrane /Collapsing in the permeate carrier/Compaction ⇨ Flux loss

Can be originated by:

- Water hammer
- Too high pressure
- Too high temperature

Intrusion of the membrane



Mechanical Damages

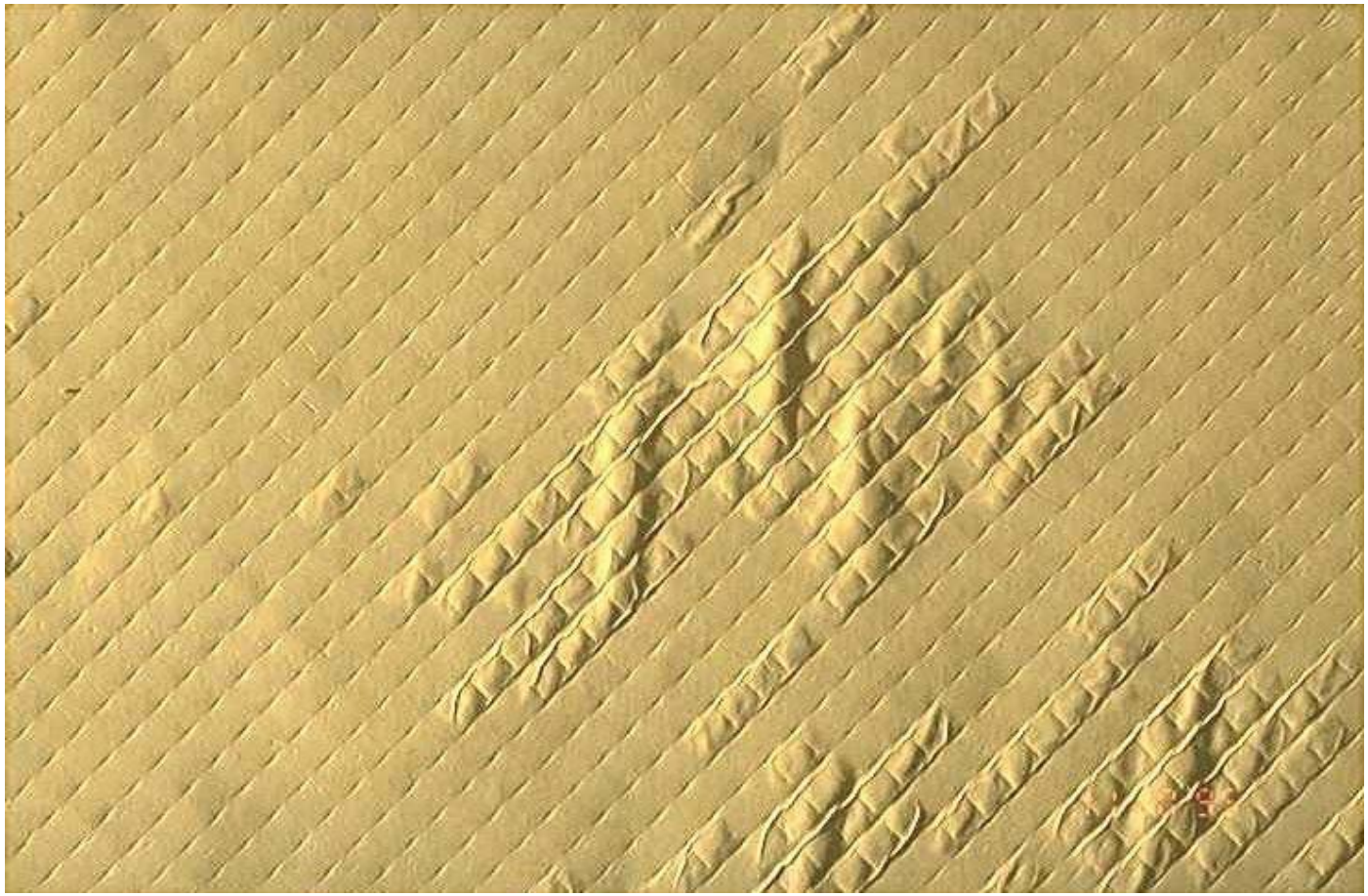
Permeate backpressure damage

⇨ Increased salt passage

Delamination and tearing of the membrane

- if permeate pressure > concentrate pressure
- typically during shut-down
- typically tail-end elements affected
- can be localized by probing
- positive leak test of element

Permeate backpressure damage



Effect on membrane performance if something goes wrong

- Fouling / Scaling
- Mechanical damages
- **Chemical damages**

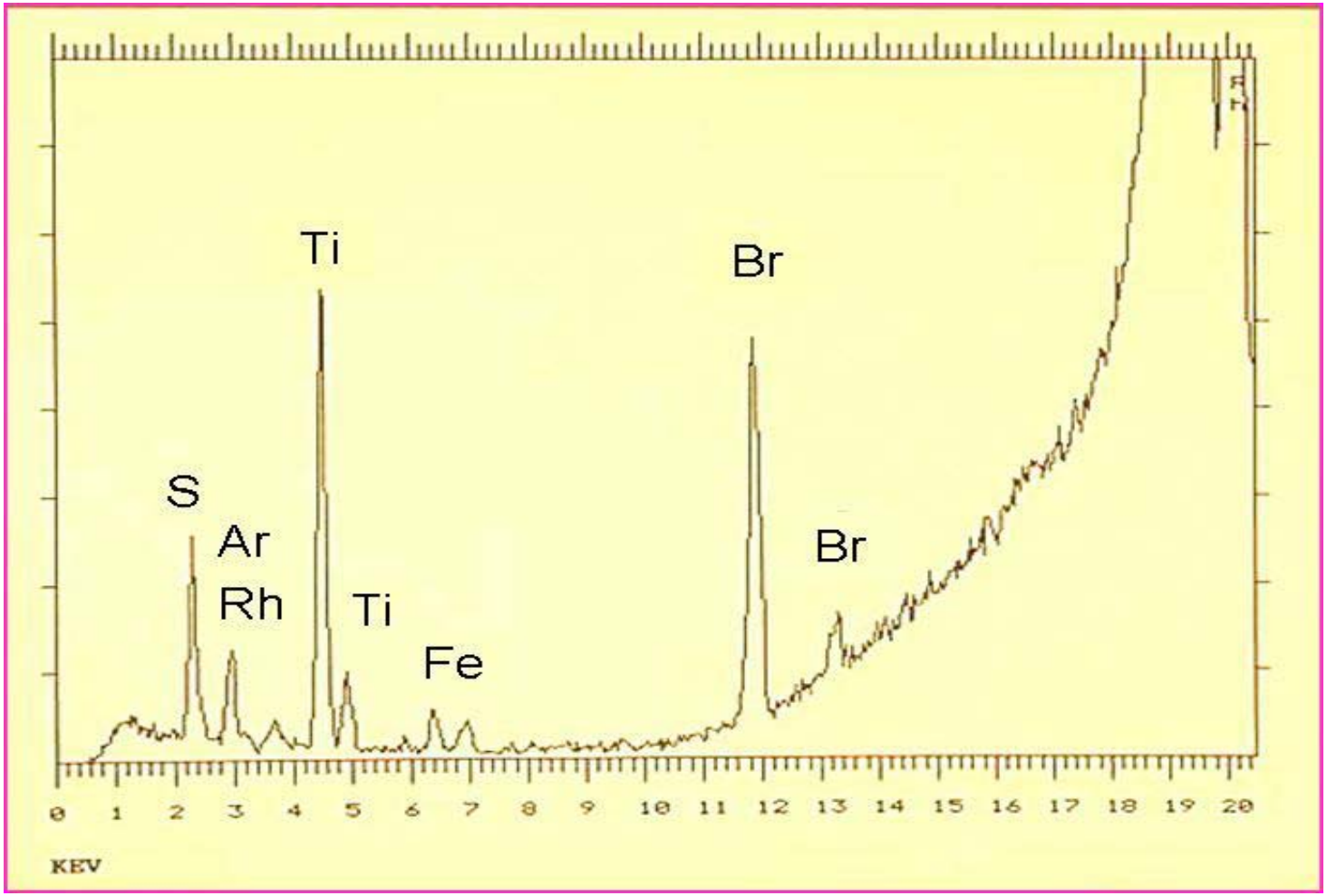
Chemical Damages

- **From Chemicals**
  - in feed water
  - in cleaning solutions
  - in disinfecting solutions
  - in preservation solutions

  - Strong acids (pH<1)
  - Strong alkalines (pH>13)
  - Solvents

- **Oxidation of the barrier layer by**
  - free chlorine
  - other oxidizing agents

Oxidation damage



Chemical Damages

- **From Chemicals**
  - in feed water
  - in cleaning solutions
  - in disinfecting solutions
  - in preservation solutions

  - Strong acids (pH<1)
  - Strong alkalines (pH>13)
  - Solvents

- **Oxidation of the barrier layer by**
  - free chlorine
  - other oxidizing agents

Correction:	Membrane replacement
Prevention:	Dechlorination, ORP control, chemicals selection

Troubleshooting in RO und NF Plants

Contents

Problem area: Feed water/Pretreatment

- **Feed water quality may change**

Problem area: Feed water/Pretreatment

- **Feed water quality may change**
- **Potential problems with dosing chemicals:**
  - Dosing failure
  - No coupling of the dosing pump to the main plant
  - Over/under dosage
  - Missing / wrong / poor quality chemicals
  - Aged chemicals
  - Biological growth in stock solution
  - Insufficient mixing
  - Insufficient retention time

Problem area: Feed water/Pretreatment

- **Potential problems with flocculation:**
  - Too small flocs – carry over
  - Wrong type of flocculant / polymer
    - not efficient
    - not compatible with membrane, e.g. cationic polymers
  - Improper dosage of flocculant / polymer
    - Concentration
    - Dosing point: distribution, turbulence
    - Retention time
  - Improper pH control
  - Reaction of polymers with scaling inhibitors

Problem area: Feed water/Pretreatment

- **Potential problems with pre-filtration**
  - Breakthrough of particles due to
    - Wrong design
    - Discontinuous flow rate
    - Insufficient rinse-out
    - Too large pore size (cartridge filter)
    - Wrong filter media or size
    - Ineffective backwashing
    - Broken collectors

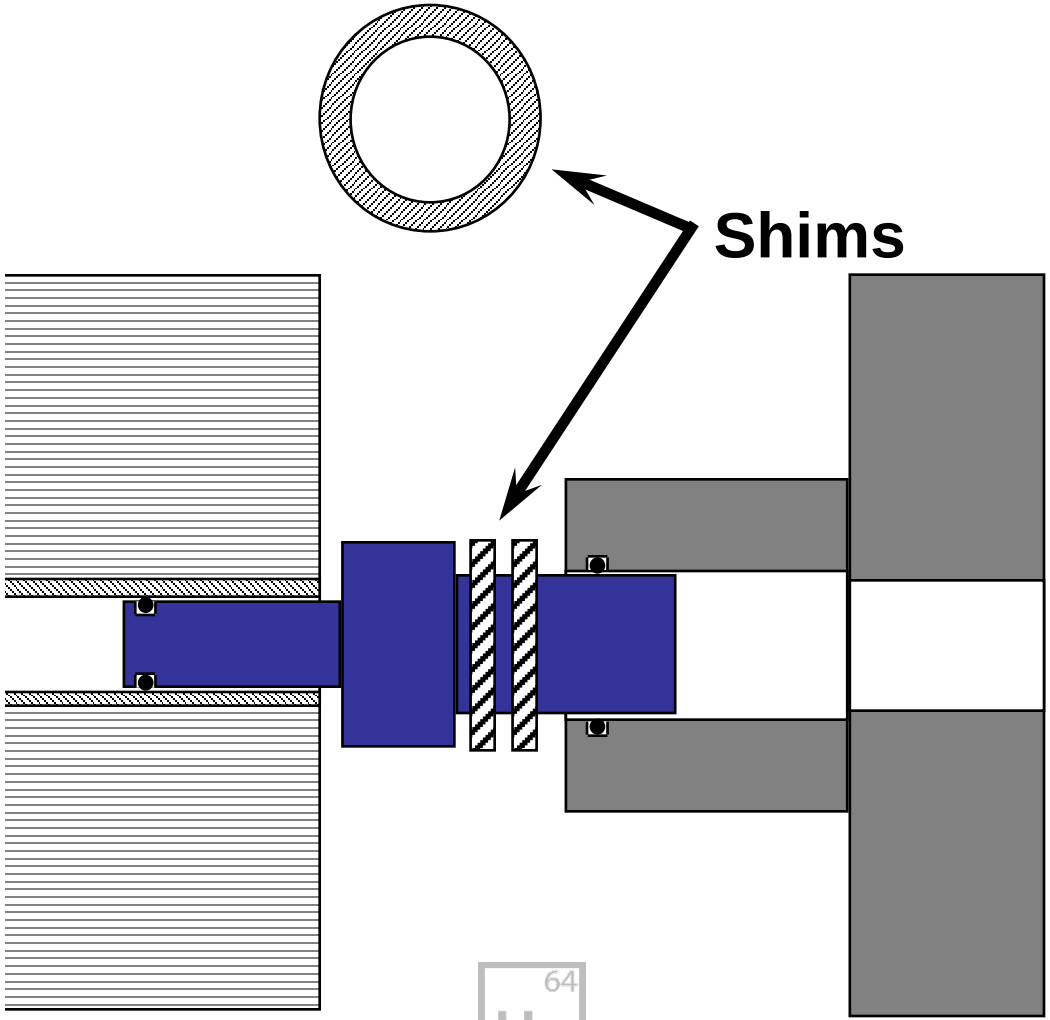
Troubleshooting in RO und NF Plants

Contents

Problem area: plant operation

- **Storage and installation of membrane elements**
  - Improper storage leads to drying out or fouling of the membranes
  - Improper installation can result in mechanical damage to O-rings, interconnectors or permeate water tube
  - Lack of shimming can lead to leakage or membrane mechanical damage

Shimming



Problem area: plant operation

- **Potential problems at start-up**
  - Water hammer, when the high pressure pump is started with residual air in the system

Start-up with air in system

High pressure drop / water hammer

Problem area: plant operation

- **Potential problems at start-up**
  - Water hammer, when the high pressure pump is started with residual air in the system
  - Too high system recovery ⇨ Scaling
  - Unstable pre-treatment ⇨ leaking foulants or oxidants onto the membranes.

Problem area: plant operation

- **Potential problems during normal plant operation**
  - excessive feed pressure to compensate for reduced flux, results in membrane intrusion or fouling
  - frequent start/stop operation
  - too high recovery e.g. when the feed water changes, can result in scaling
  - irregular cleaning
  - insufficient pre-treatment
  - no performance evaluation

Problem area: plant operation

- **Potential problems during shut-down**
  - Residual pre-treatment chemicals (e.g. scale inhibitors) may precipitate in the system ⇨ flush with high quality water
  - Air entering the system can lead to a water hammer upon start-up ⇨ vacuum breaker
  - A pressurized permeate line may cause a permeate backpressure damage ⇨ check valve, pressure relief valve

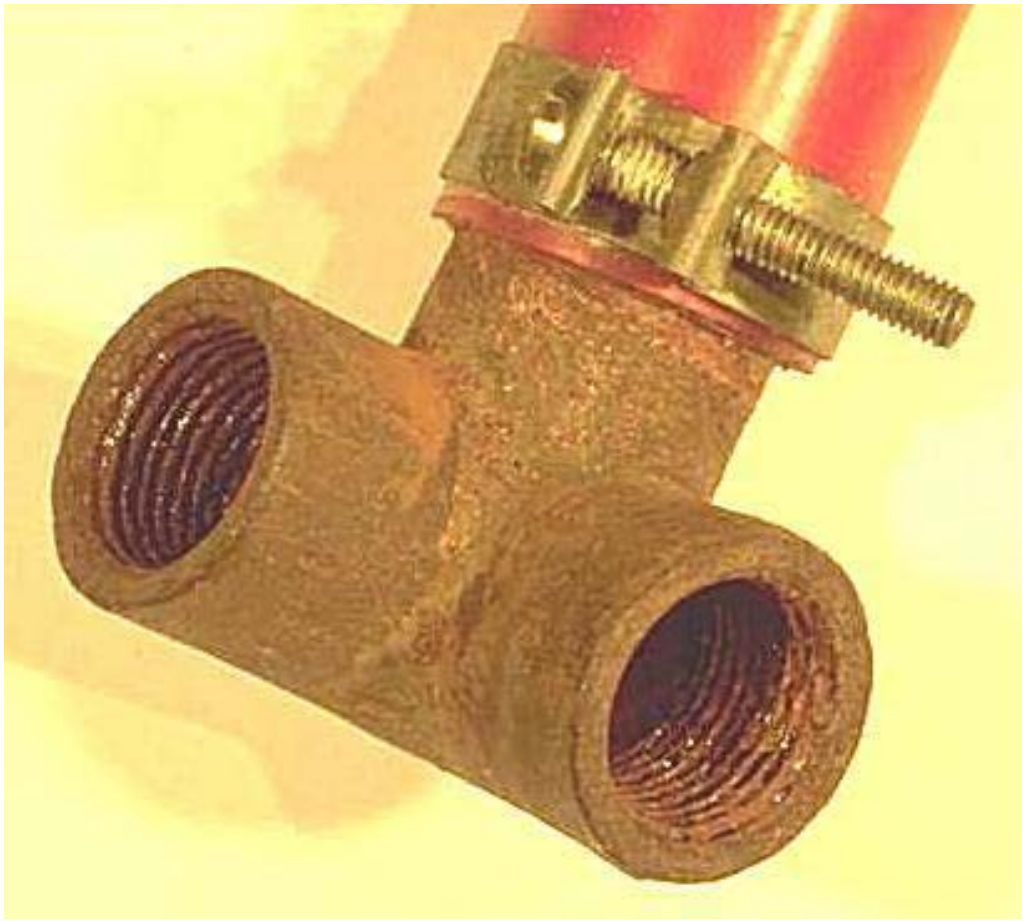
Troubleshooting in RO und NF Plants

Contents

Problem area: system components

- **Pumps**
  - Impeller deterioration releases shavings onto the lead elements
  - Excessive pulsations can cause mechanical damage
- **Instrumentation**
  - Faulty, missing or wrongly calibrated
- **Pressure vessels**
  - Too small diameter double side ports ⇨ poor flow distribution ⇨ scaling / fouling
  - Incorrect end adaptors ⇨ leakage / membrane delamination
- **Corrosion**
  - Improper material selection ⇨ metal oxide fouling

Corrosion



Troubleshooting in RO und NF Plants

Contents

6. Troubleshooting Summary

Source of problems	Effect on membranes	Symptoms observed			Corrective measures
		Permeate Flow	Permeate Salt conc.	Pressure Drop	
Feed water	Scaling, fouling	↓	↑	↑	Clean
	Mechanical damage (compaction)	↓	↓	Normal	Replace elements
Pre-treatment: chemical dosing, Floc, lime, resin	Scaling, fouling	↓	↑	↑	Clean or replace elements
Pre-treatment: chemical dosing	Oxidative damage	↑	↑	Normal	Replace elements
Pre-treatment: pre-filtration	Colloid fouling	↓	↑	↑	Clean or replace elements
Plant operation: storage	Biofouling, incomplete wetting	↓	Normal	↑	Clean / re-wet
Plant operation: installation, start-up	Leaks, mechanical damage	Normal	↑	Normal or ↑	Repair leaks/replace elements
Plant operation: control	Scaling, fouling	↓	↑	↑	Clean
Plant operation: shut-down	Biofouling, sulfur fouling	↓	Normal	↑	Clean

Corrective Measures

- FILMTEC™ membranes and element components can be very effectively cleaned due to their pH and temperature resistance. However, if cleaning is delayed, it becomes increasingly difficult to remove foulants from the membrane surface. Cleaning will be more effective if it is tailored to the specific fouling problem.

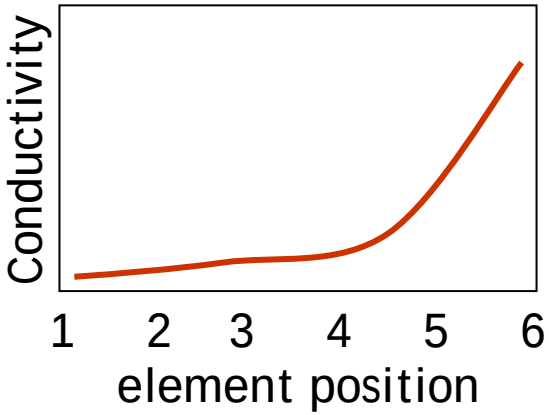
- Oxidized or Mechanically Damaged Elements cannot be restored as the membrane has been irreversibly damaged. The elements need to be replaced. Elements with moderate telescoping may be still usable.

Problem	Corrective measures	Prevention possibilities
Biofouling	Clean	Renew old preservation solution for stored membranes. Check feed water for biofouling potential. Shock treat feed stream with non-oxidizing biocide or SBS during normal operation for limited time. Consider installing bioreactor upstream. Use micro/ultrafiltration to remove micro-organisms. Install fouling resistant (FR) elements.
Scaling	Clean	Check feed water for scaling potential at current system recovery. Analyze feed water, permeate and concentrate for potential scaling ions. Inspect concentrate side of system for scaling. Install or optimize acid or antiscalant pre-treatment. Add ion exchange or lime softener. Preventative regular cleaning/flushing. Lower recovery to eliminate precipitation risk.
Organic fouling	Clean (difficult)	Add pre-treatment if feed water TOC > 3 mg/L. Install/optimize coagulation, UF or active carbon. Coagulation / active carbon if oils & greases > 0.1mg/L. Consider oil/water separators as pretreatment.

Problem	Corrective Measures	Prevention possibilities
Particle/Colloid fouling	Clean (difficult)	Replace corroded system components. Install or optimize pre-filtration pretreatment. Add coagulation/flocculation for Fe and colloids. Poor pre-treatment may be partly compensated by more frequent and/or harsher cleaning.
Mechanical Damage	Replace elements	Eliminate high pressure/water hammer (air in system) to avoid telescoping, compaction or product water tube damage. For surface abrasion: flush line and install cartridge filtration. For delaminated membranes, eliminate source of high static permeate backpressure. Develop protocol for correct element installation.
Oxidative damage	Replace elements	Remove oxidizing chemicals upstream of membranes e.g. SBS dosing. Add activated carbon filter. Replace corroded system components (metals act as oxidative catalyst).
Leaks	Repair or replace	Remove source of water hammer if appropriated. Develop program to inspect and replace old O-rings. Develop protocol for correct element installation. Profiling, probing.

Example

- High permeate conductivity suddenly after the plant start up
- By probing high conductivity was localized at the rear elements of the second stage. (The plant has 2 stages.)



- Bubble test of rear elements gave a positive result (bubbles appeared from the scroll).

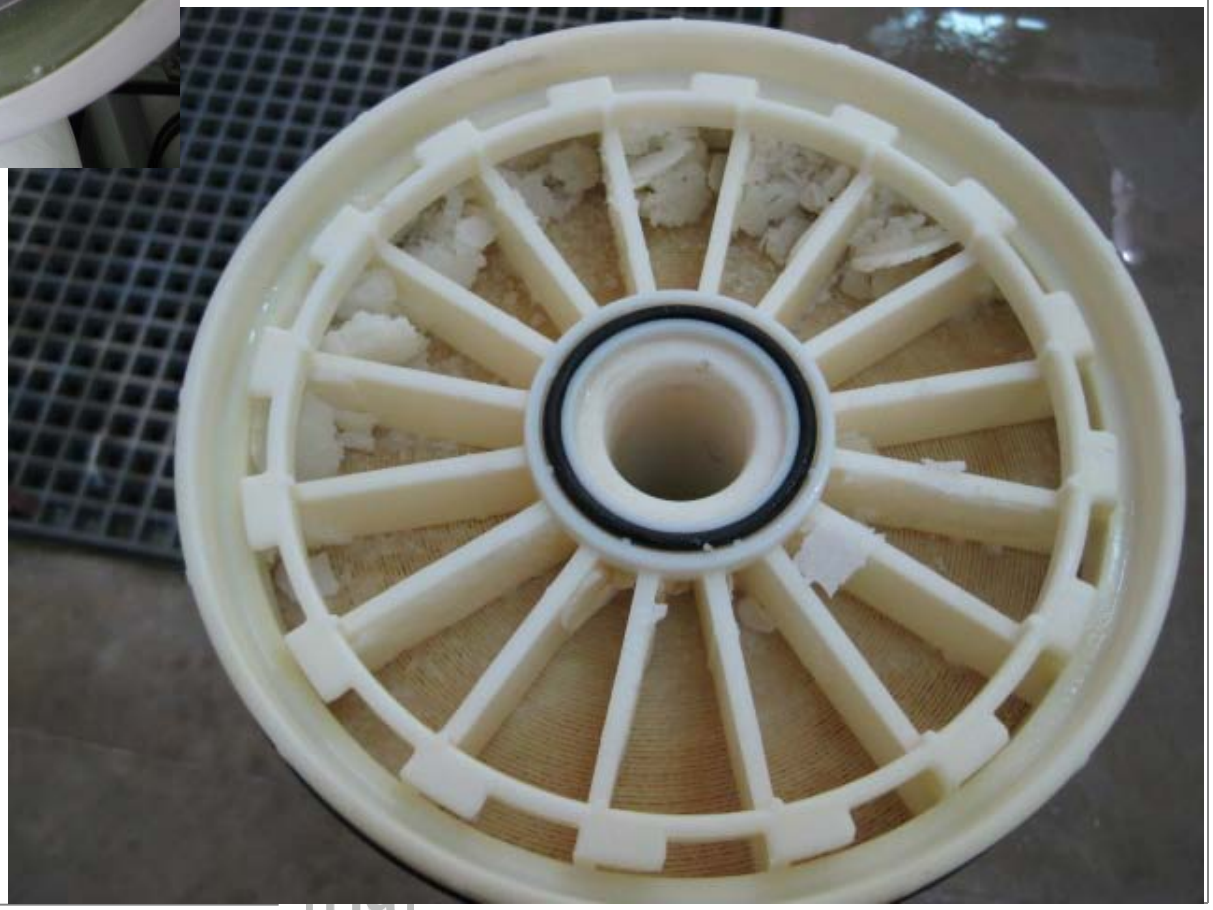
Example - Autopsy

Element	Flow [m^3/d]	Rejection [%]	Δ P [bar]
Nominal	47.8	99.3	0.3
Example	46	90	0.6

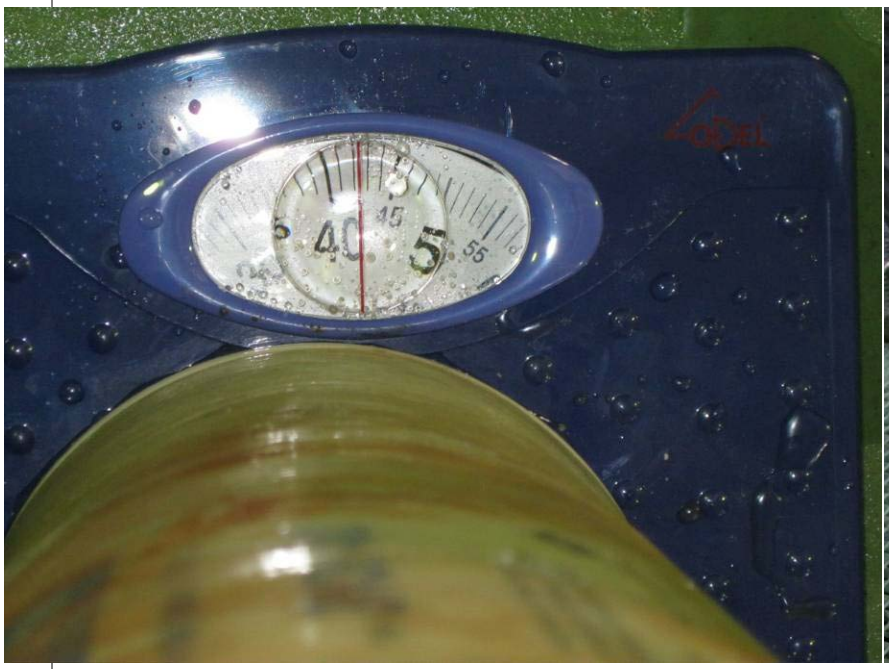
Problem: Too high back-pressure as a result of improper shut down procedure.

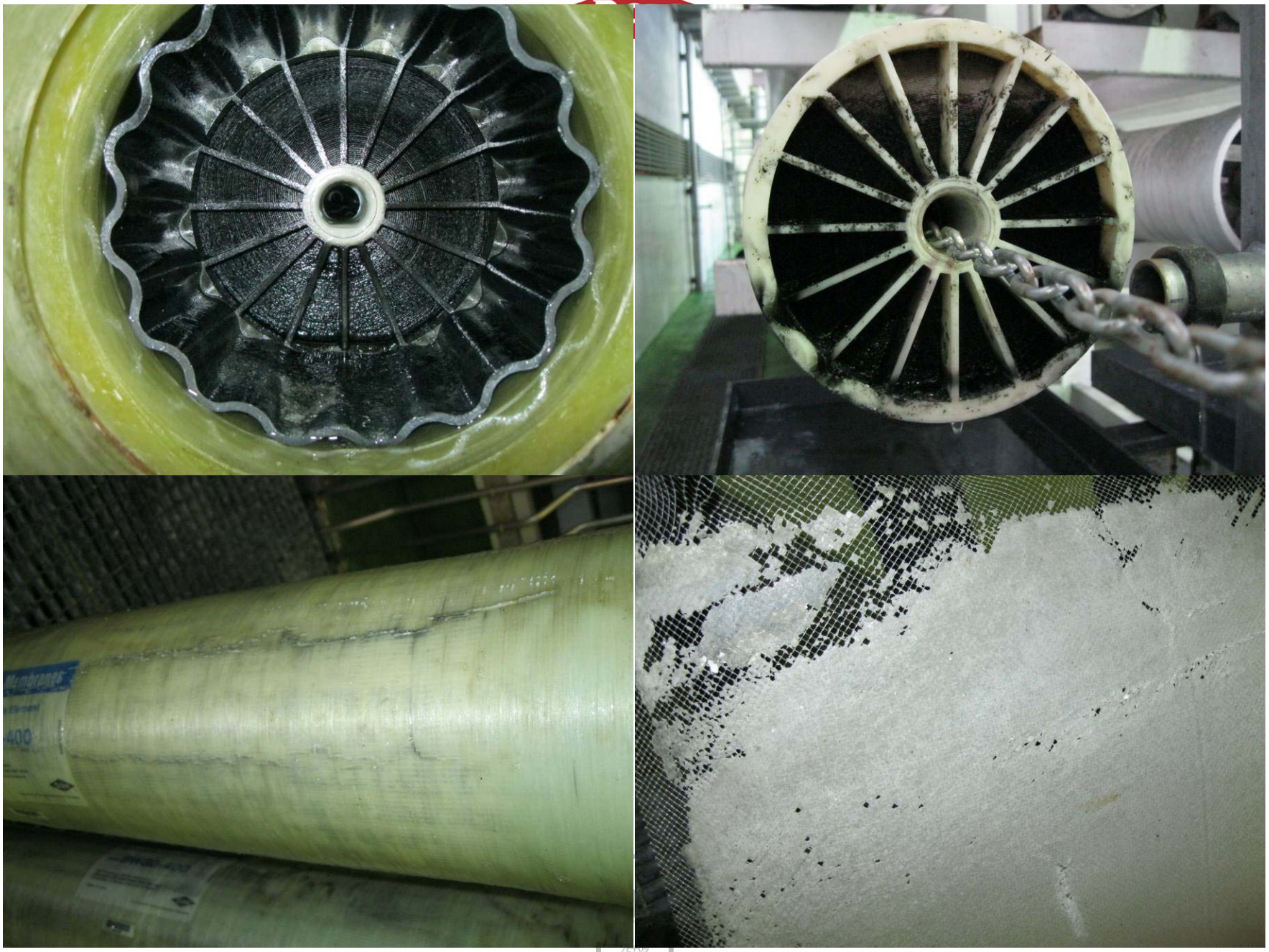
Example: Scaling

Membrana	Peso (kg)
F3013503	24
F3013352	25.5
F3013348	31
F3013508	30.5
F3151704	31
F2915947	23
Normal	14-15



Example: Fouling / Scaling





Membranes in service 2003 -2010

We wish you a trouble free operation of your membranes!