REVERSE OSMOSIS TRAINING

MIDWATER

TYPES OF MEMBRANES

- MICROFILTRATION (MF).
- ULTRAFILTRATION (UF).
- NANOFILTRATION (NF).
- REVERSE OSMOSIS (RO).

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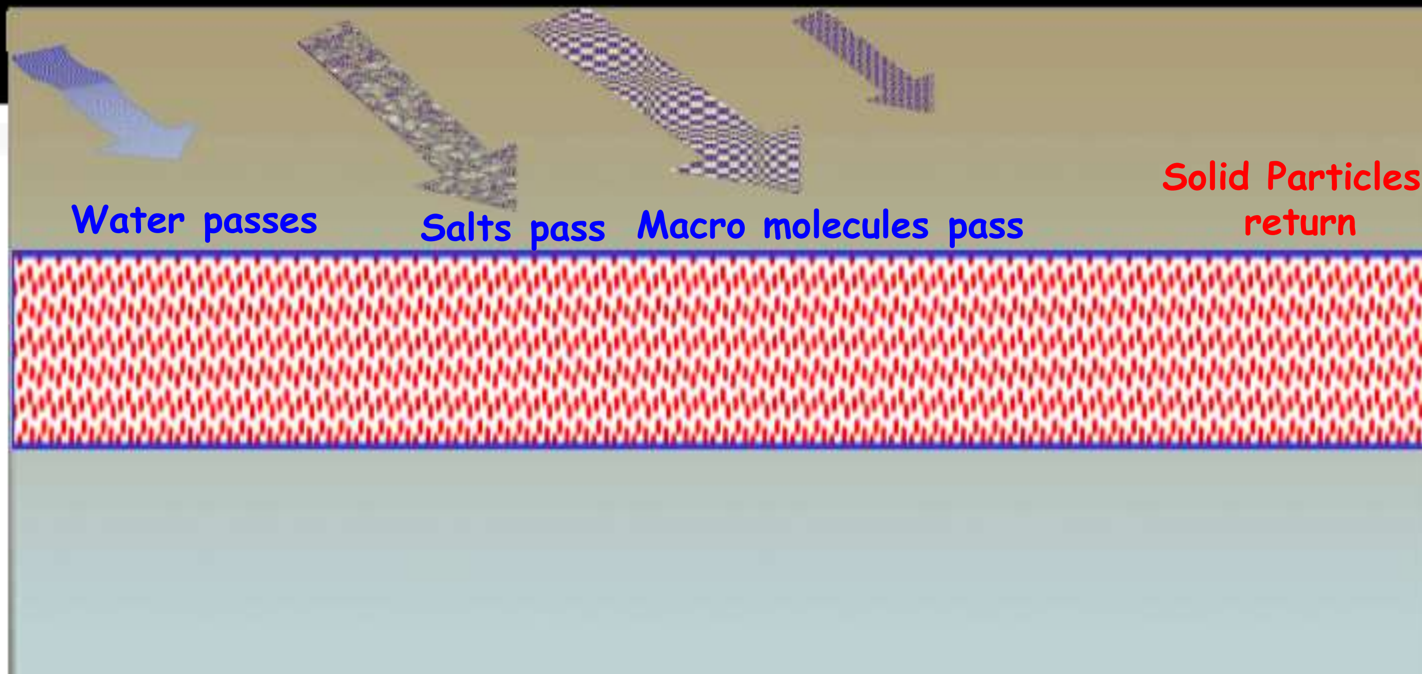
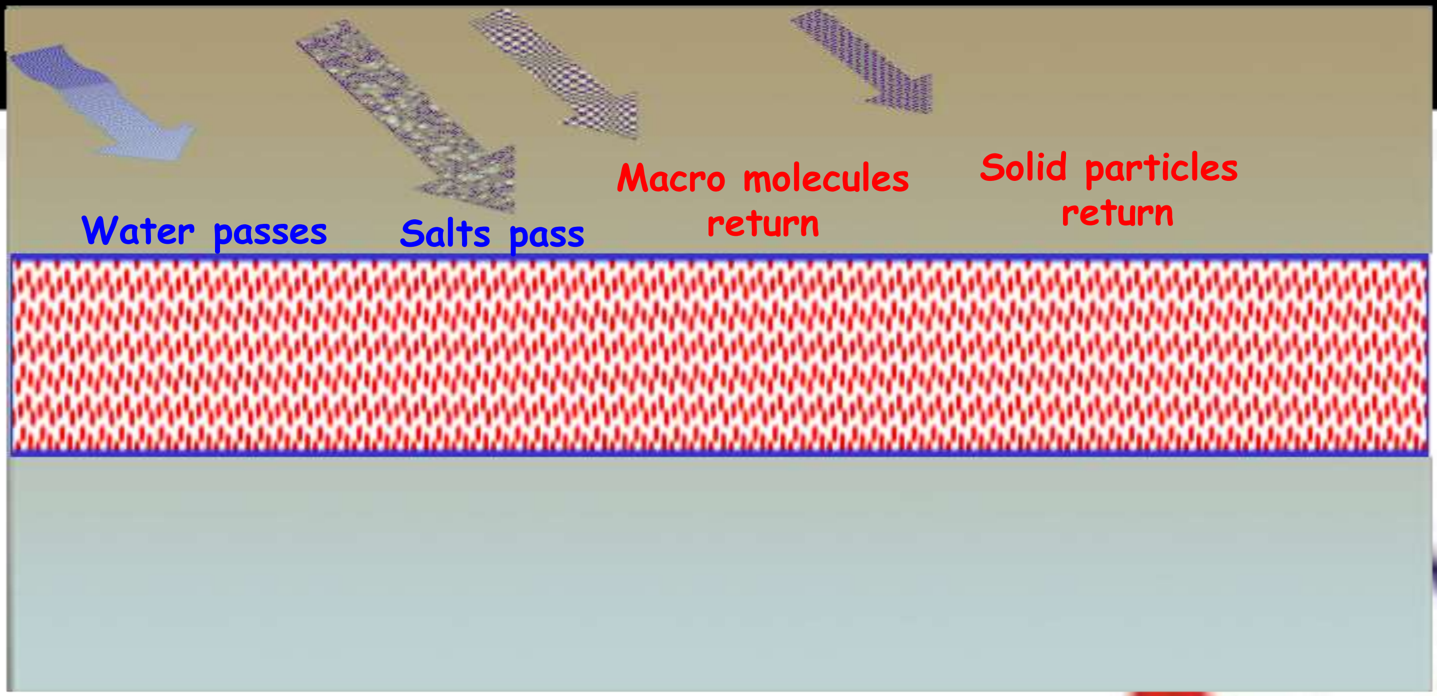
MICRO FILTRATION



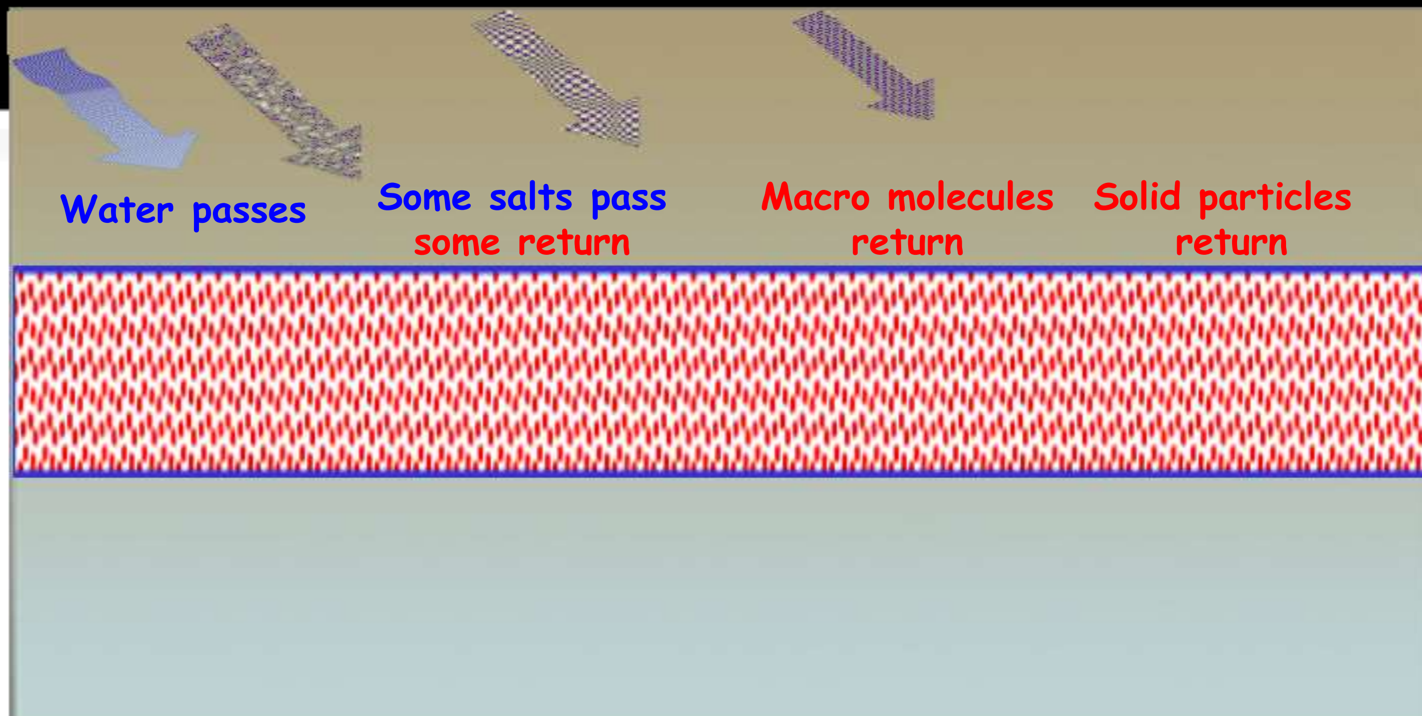
Applied Pressure	Minimum Particles size removed	Application(Type, average removal efficiency)
0.3- 1 Bar	0.1- 1 μm	Particle/turbidity removal (>99%) Bacteria/protozoa removal (>99.99 %)

ULTRA FILTRATION



Applied Pressure	Minimum Particles size removed	Application(Type, average removal efficiency)
1 - 7 Bar	0.01-0.1 µm	Particle/turbidity removal (>99%) Bacteria/protozoa removal (>99.99 % TOC removal (<25%) High removal of Virus and other patogens removal

NANO FILTRATION



Applied Pressure

3.5 - 16 Bar

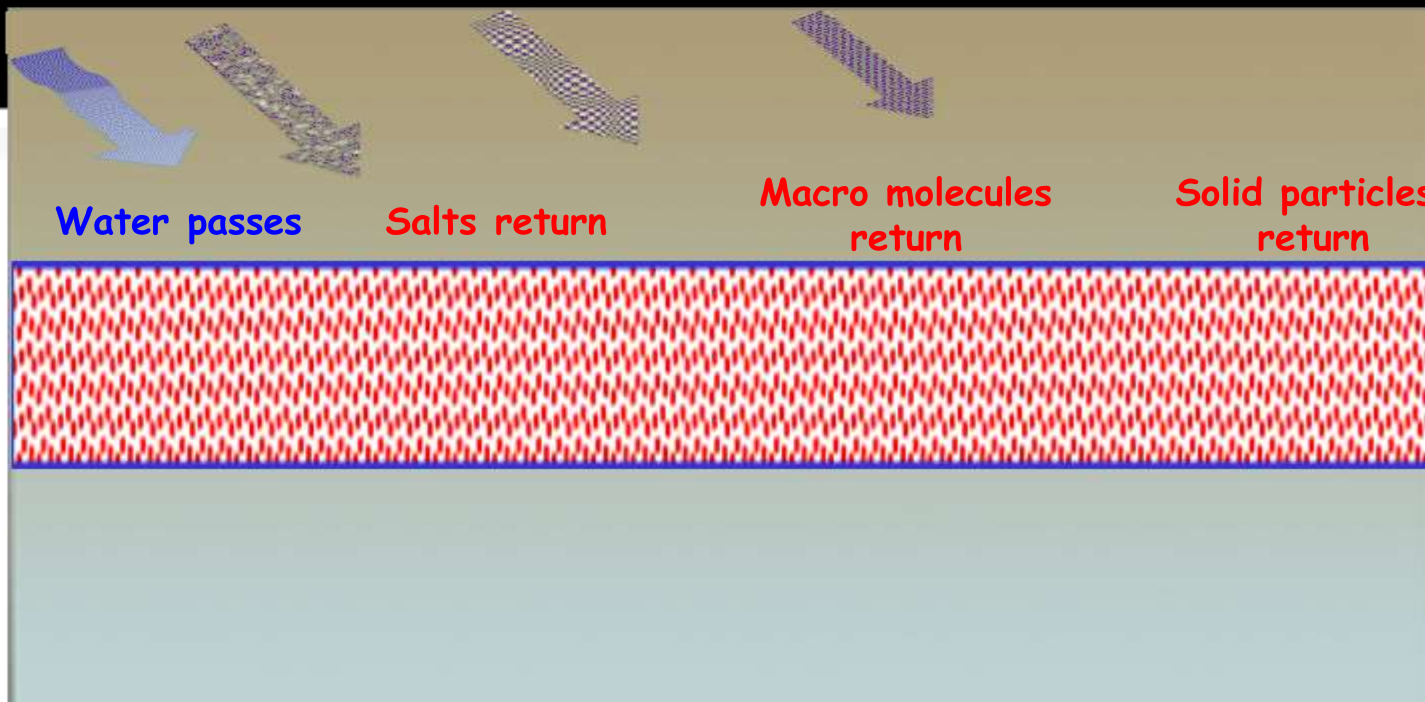
Minimum Particles size removed

200-400 daltons

Application(Type, average removal efficiency)

Turbidity removal (>99%)
Color removal (>98%)
TOC removal (>95%)
Hardness removal (softening) (>90%)
Sulfate removal (>97%)
Virus removal (>95%)

REVERSE OSMOSIS



Applied Pressure	Minimum Particles size removed	Application (Type, average removal efficiency)
9 - 69 Bar	50-200 daltons	Salinity removal (>99%) Color removal (>97%) Nitrate removal (85-95%) Hardness removal (softening) (>90%) Virus removal (>95%)

MIDWATER

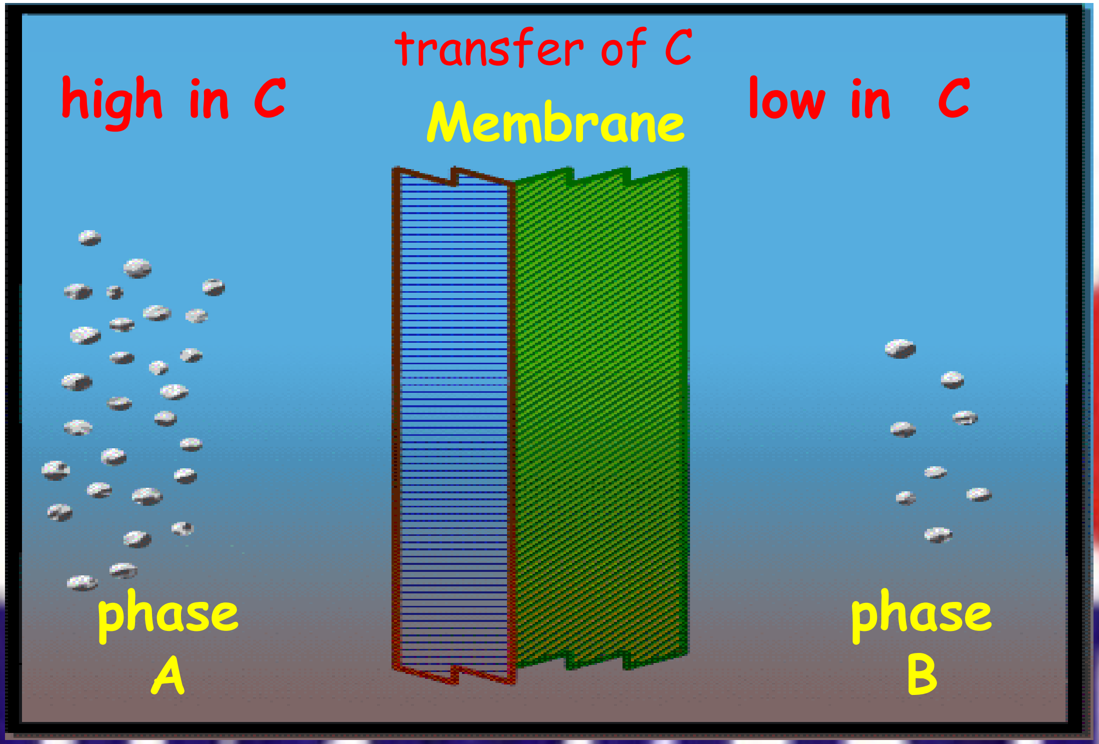
ADVANTAGES OF R.O

- Removal of Dissolved Compounds
- Low Energy Requirements
- Minimal Use of Chemicals
- Environmentally Friendly
- Modular

DEFINITION AND COMMON TERMINOLOGIES

MEMBRANE: **A selective barrier between <u>TWO PHASES</u> that allows one phase to pass through, while the other phase will be rejected.**

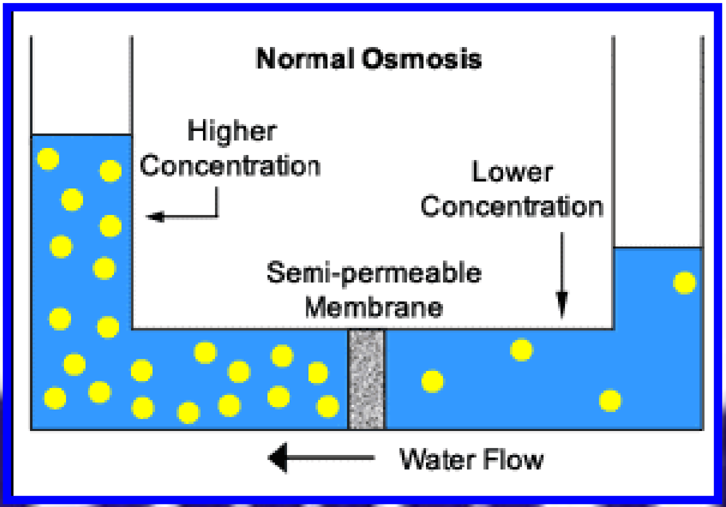
SELECTIVITY : **The ability of the membrane to differentiate between two phases.**



OSMOTIC PRESSURE

Osmosis: Natural movement of water from a less concentrated solution into a more concentrated solution with respect to the solute across two sides of a semi-permeable membranes.

Osmotic Pressure: The hydraulic pressure generated naturally by the imbalance of salt concentrations across a semi-permeable membrane.



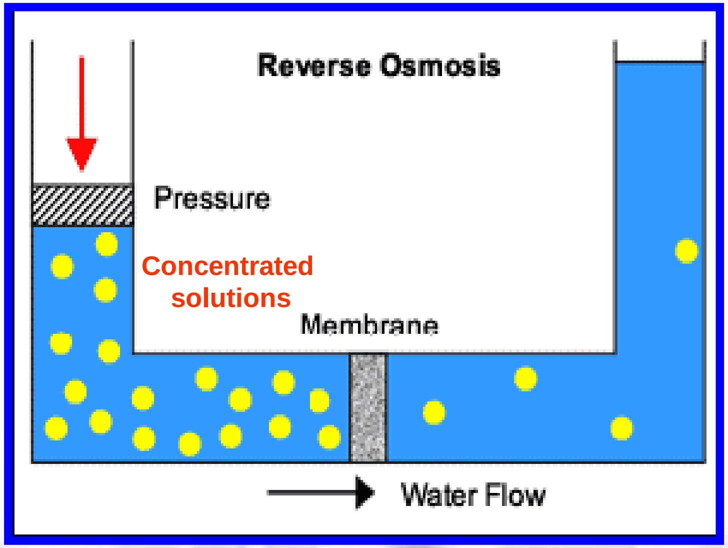
OSMOTIC PRESSURE

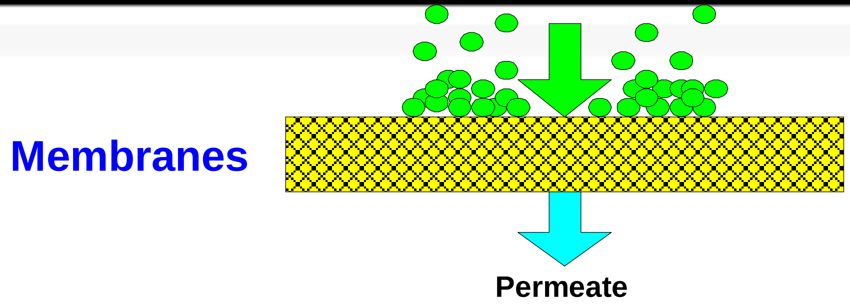
$$\pi = k.C$$

π : Osmotic pressure
k : Constant, [bar/(mg/L)]
C : TDS [mg/L]

Water quality	TDS [mg/L]	k [bar/(mg/l)]	π à 25°C [bar]
NaCl solution	2 000	$8,34 \times 10^{-4}$	1,67
Sea water	35 000	$3,59 \times 10^{-4}$	27,3
Brackish water	2 000	$7,79 \times 10^{-4}$	1,06
CaSO4 solution	2 000	$5,31 \times 10^{-4}$	0,72

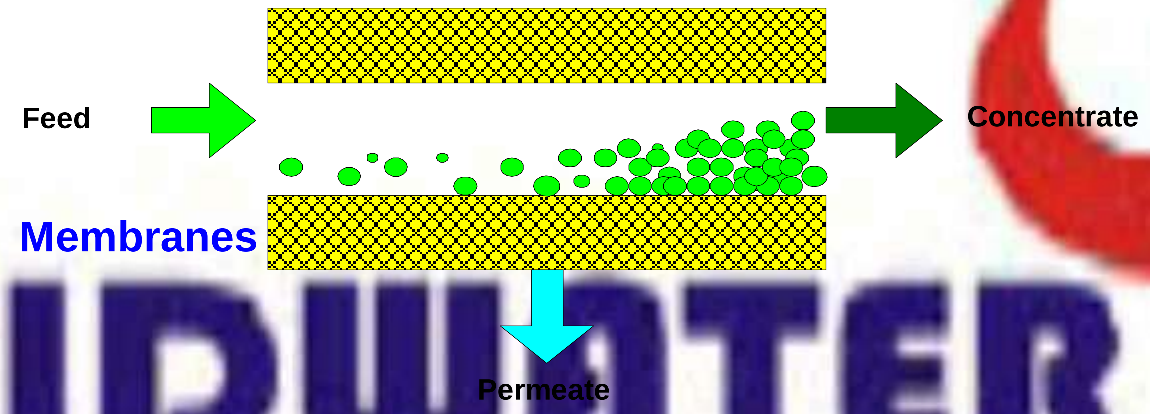
Reverse Osmosis (RO): A pressure-driven process developed by man where water is mechanically forced to flow in a reverse direction through a semi-permeable membrane from a solution of high salt content to a solution of lower salt concentration. This reverse flow will not start until the osmotic pressure is overcome



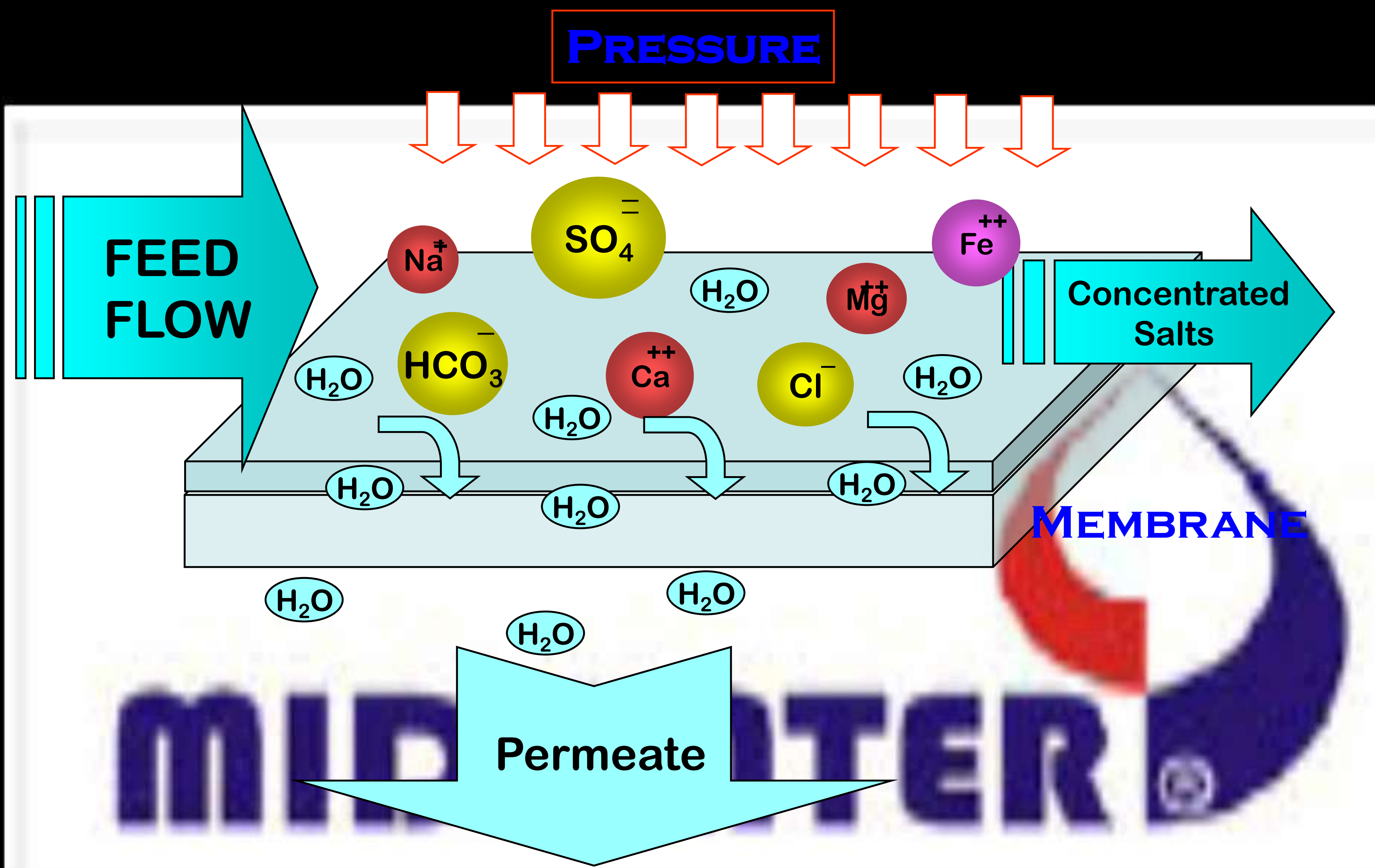


Cross flow Filtration

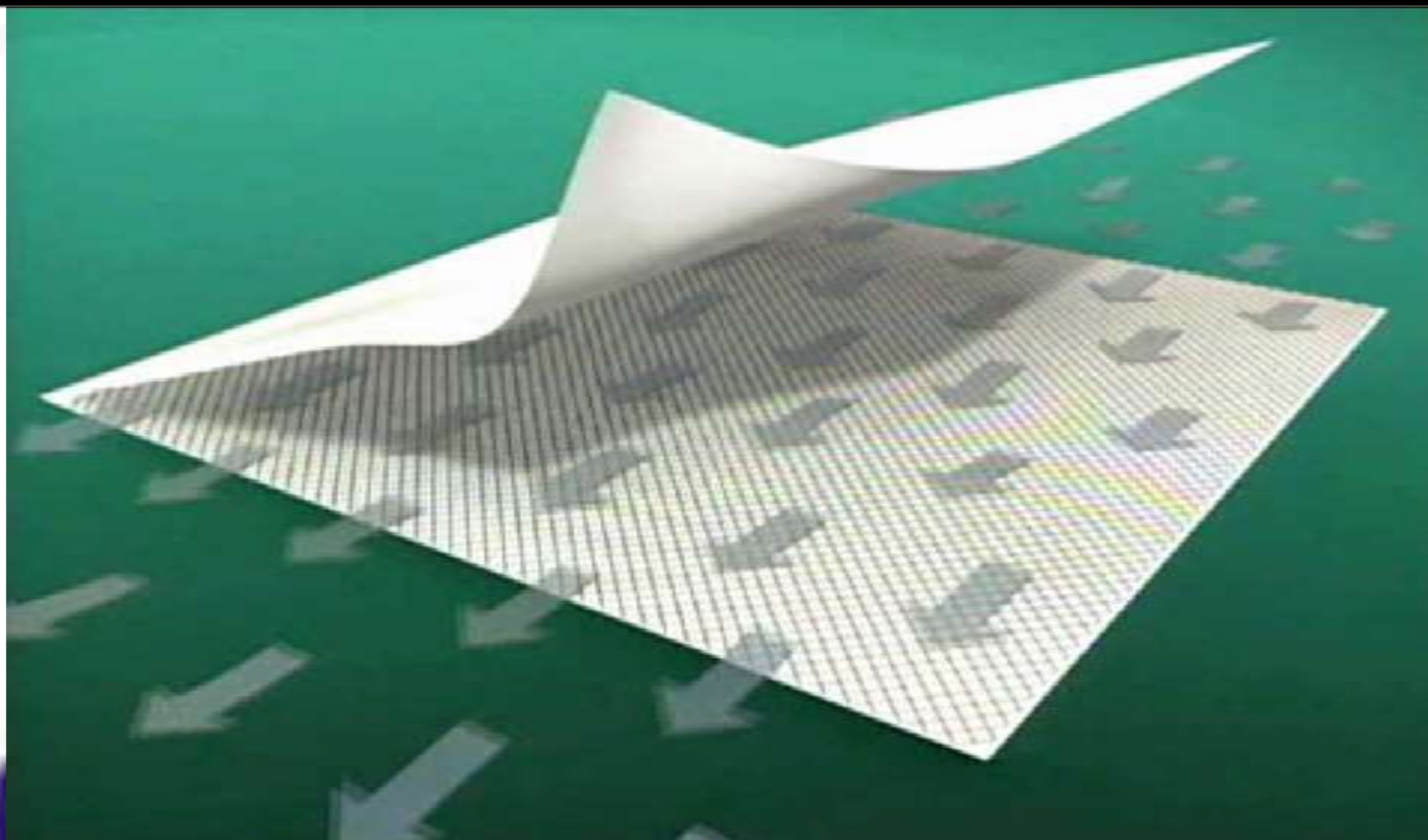
3 Streams



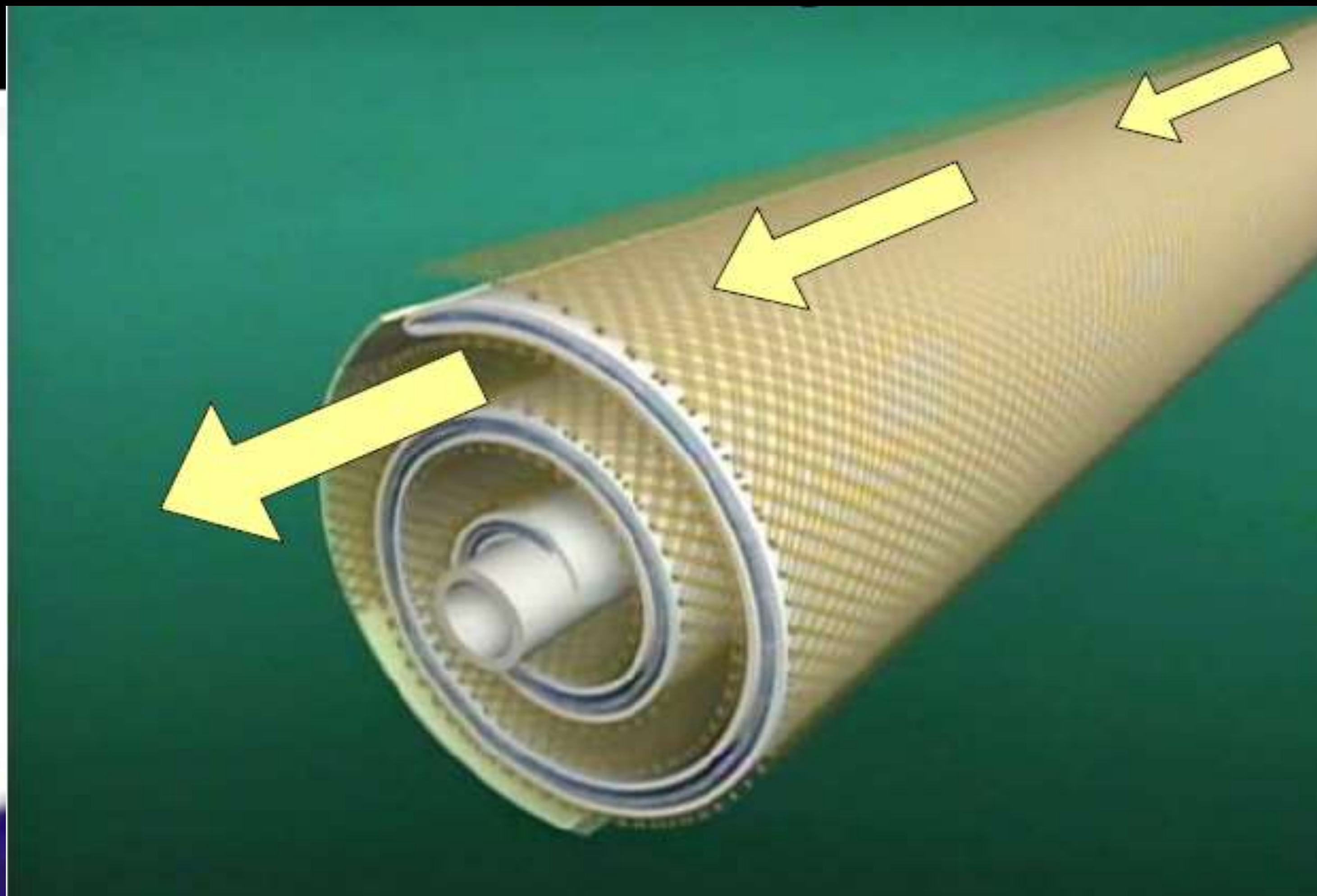
RO Membrane Separation Mechanism
CROSS-FLOW PROCESS



Cross Flow in a Spiral Element Sheet

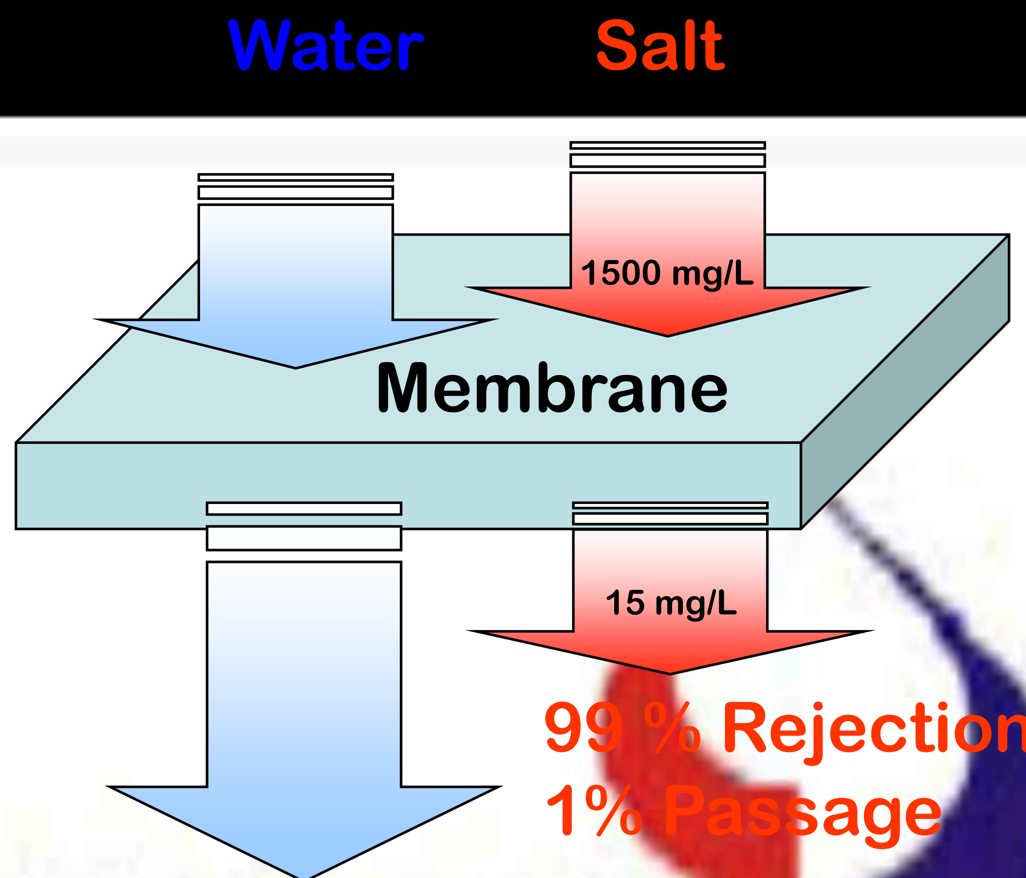


Cross Flow in A Spiral Wound Element Removes Rejected Material



IMPORTANT MEMBRANE CHARACTERISTICS

- 1.Salt Rejection
- 2.Salt Passage
- Water Flow
- Specific Flux



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SEPARATION THEORY BY A RO MEMBRANE

Two Transport Models exist:

1. **Physical Pore Size.**
2. **Chemical Diffusion.**

Current scientific thinking suggests that the physical (porosity) and chemical (diffusion) nature of the semi-permeable RO membrane determines its ability to allow for the preferential transport of water over salt through the membrane.

TYPES OF MEMBRANE - Material

TWO TYPES OF MEMBRANES ARE MANUFACTURED :

- **CELLULOSE ACETATE.**
- **COMPOSITE.**

  Made of three different materials

  1. Polyester support Layer.
  2. Polysulphone interlayer.
  3. Active Layer on top.

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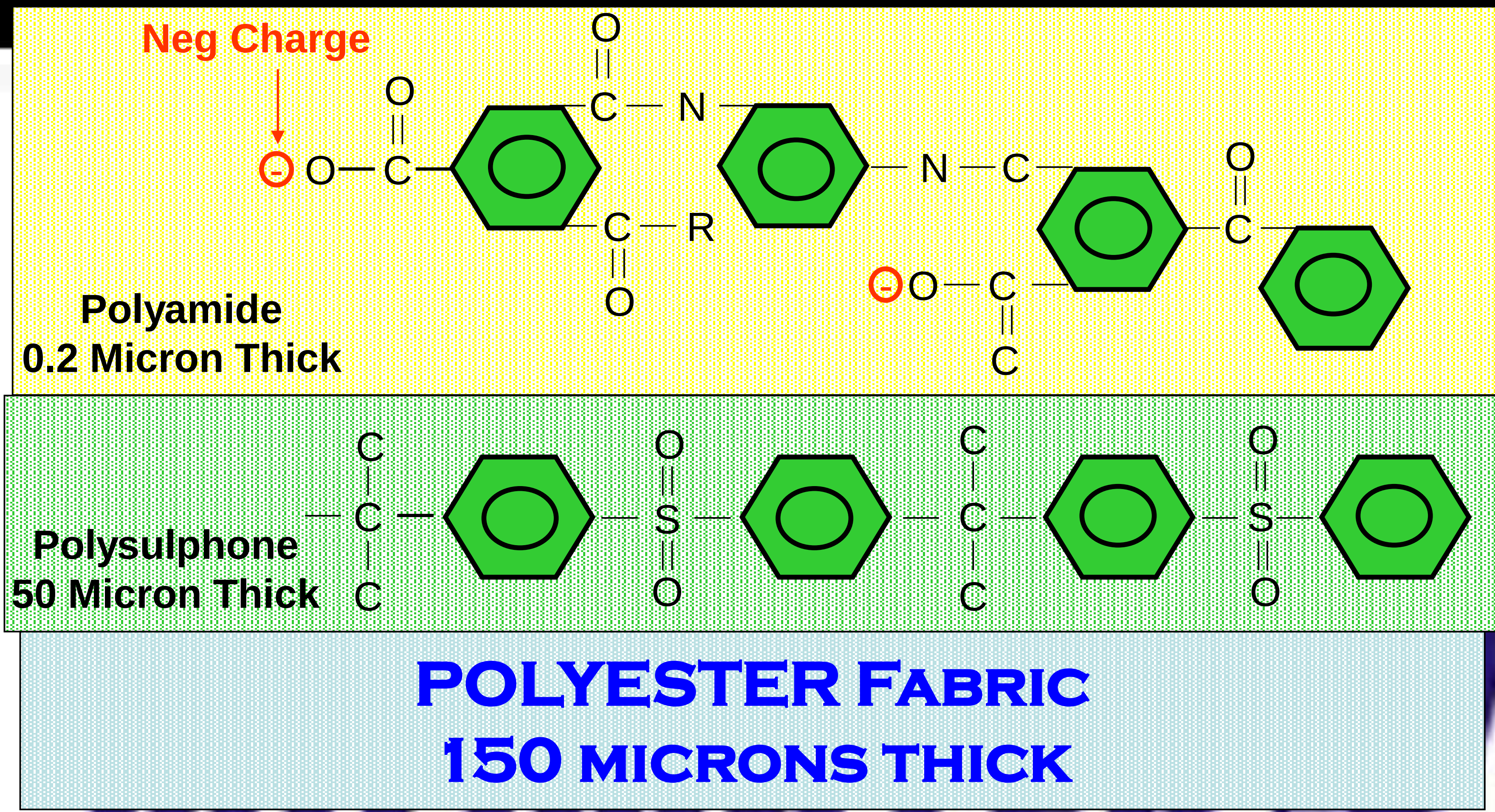
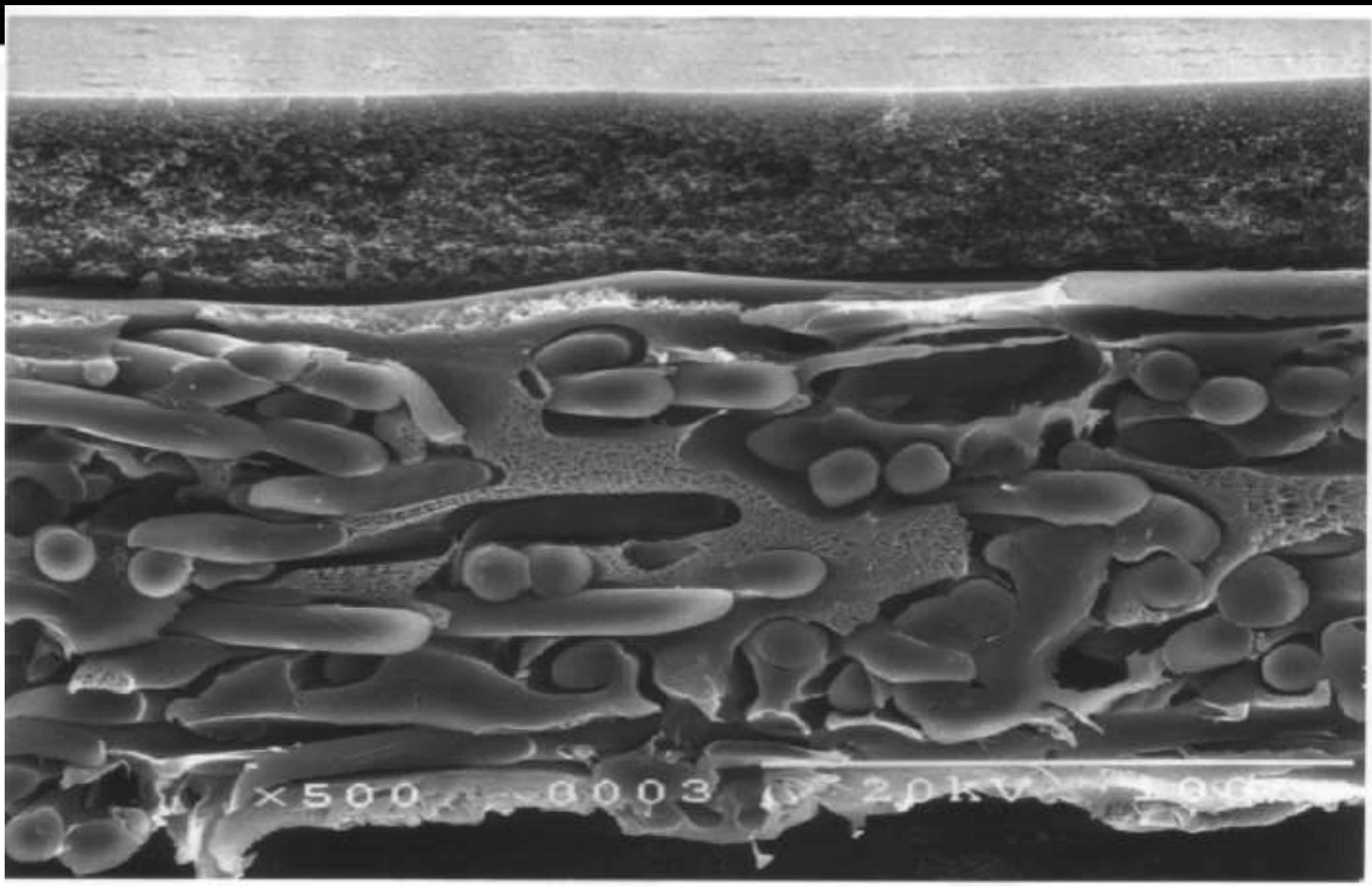
CHEMICAL COMPOSITION OF TYPICAL RO MEMBRANE



COMPOSITE PA MEMBRANE CROSS-SECTION



Ultra Thin Barrier Layer

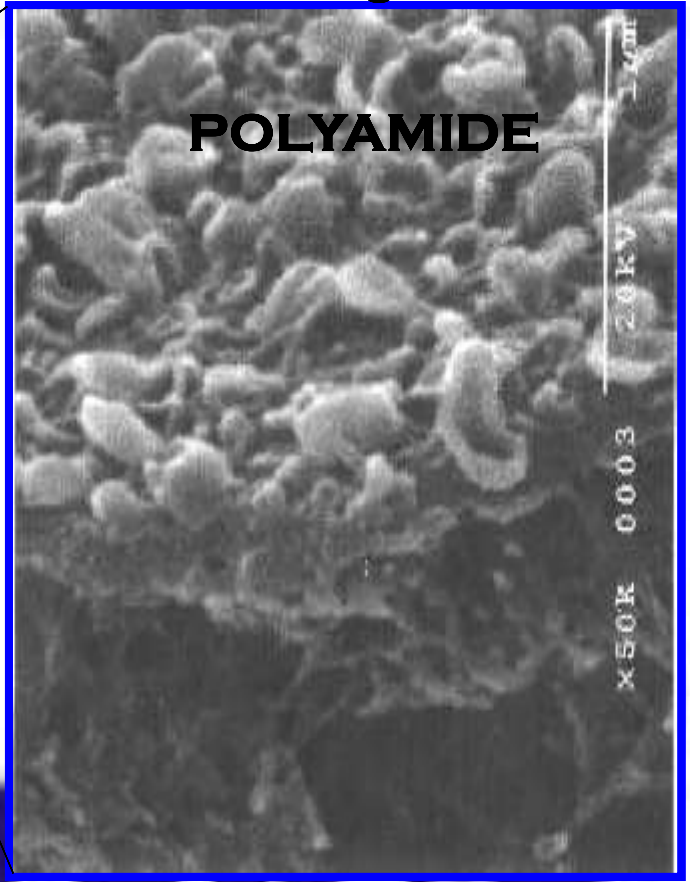
Microporous Polysulfone

Polyester Support Web

MAGNIFIED VIEW OF POLYAMIDE MEMBRANE

PA Thickness = 0.15 micron

RO membrane Side View
2000 X Magnification



MEMBRANE CONFIGURATIONS

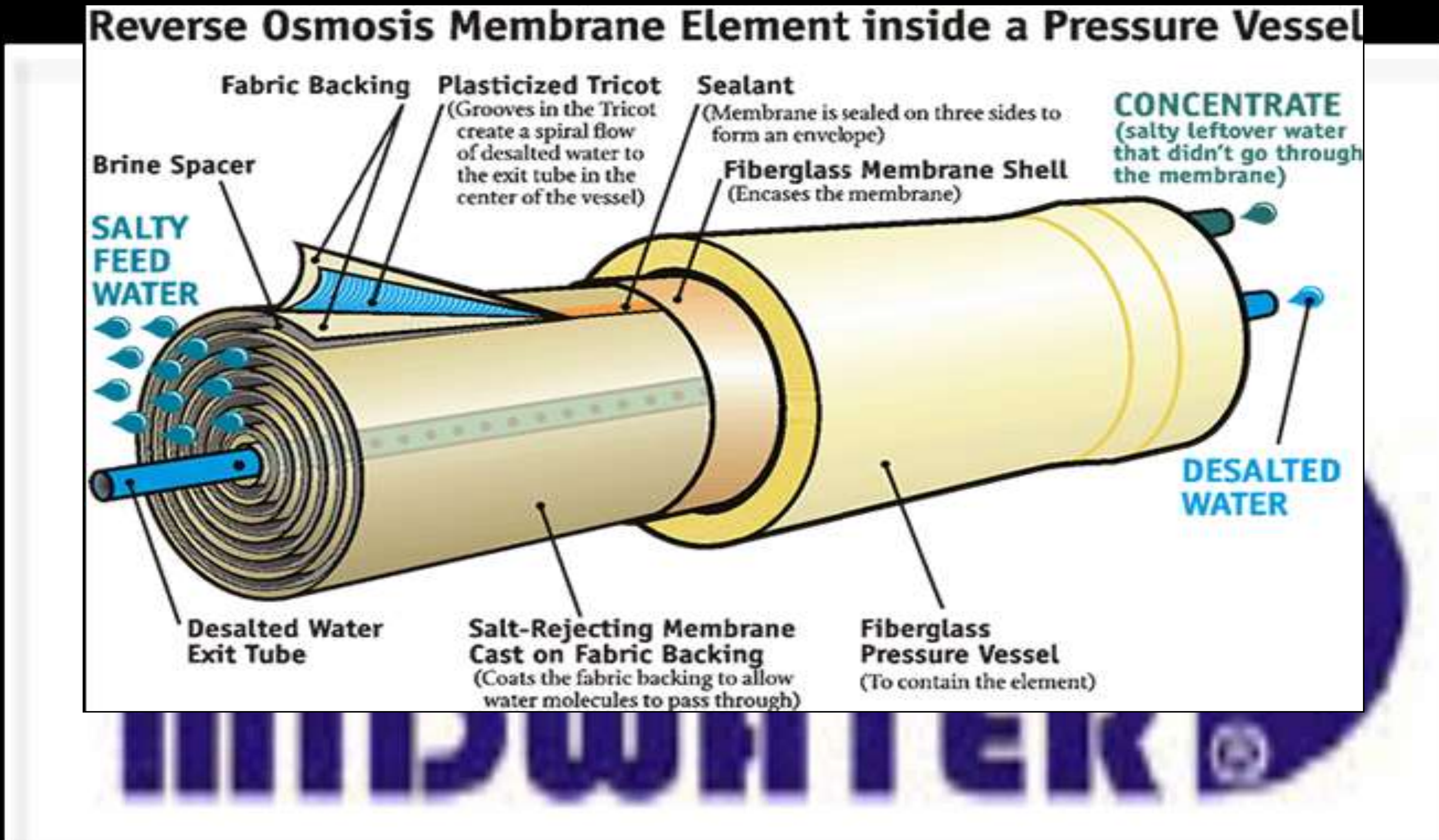
- **FOUR TYPES OF MEMBRANE CONFIGURATION :**

1. **Spiral Wound.**
2. **Hollow Fiber.**
3. **Plate & Frame.**
4. **Tubular.**

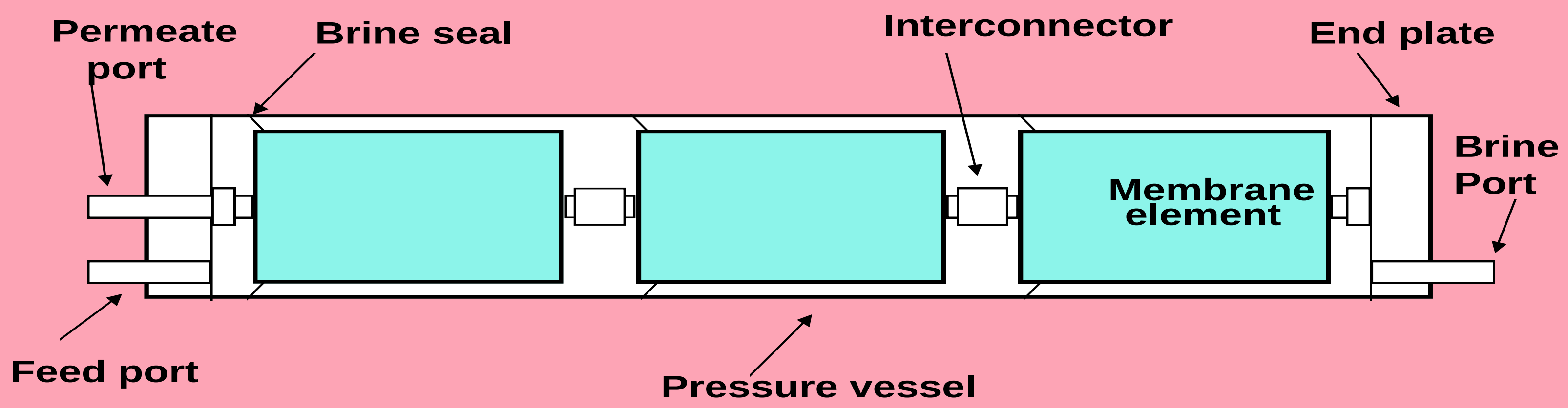
SPIRAL WOUND MEMBRANES

- In a spiral wound configuration two flat sheets of membrane are separated with a permeate collector channel material to form a leaf. This assembly is sealed on three sides with the fourth side left open for permeate to exit. A number of these assemblies or leaves are wound around a central plastic permeate tube.

RO SPIRAL WOUND ELEMENT SCHEMATIC



THIN FILM COMPOSITE MEMBRANE



Pressure Vessel with 3 Membrane Elements

SPIRAL WOUND ELEMENTS & PRESSURE VESSELS

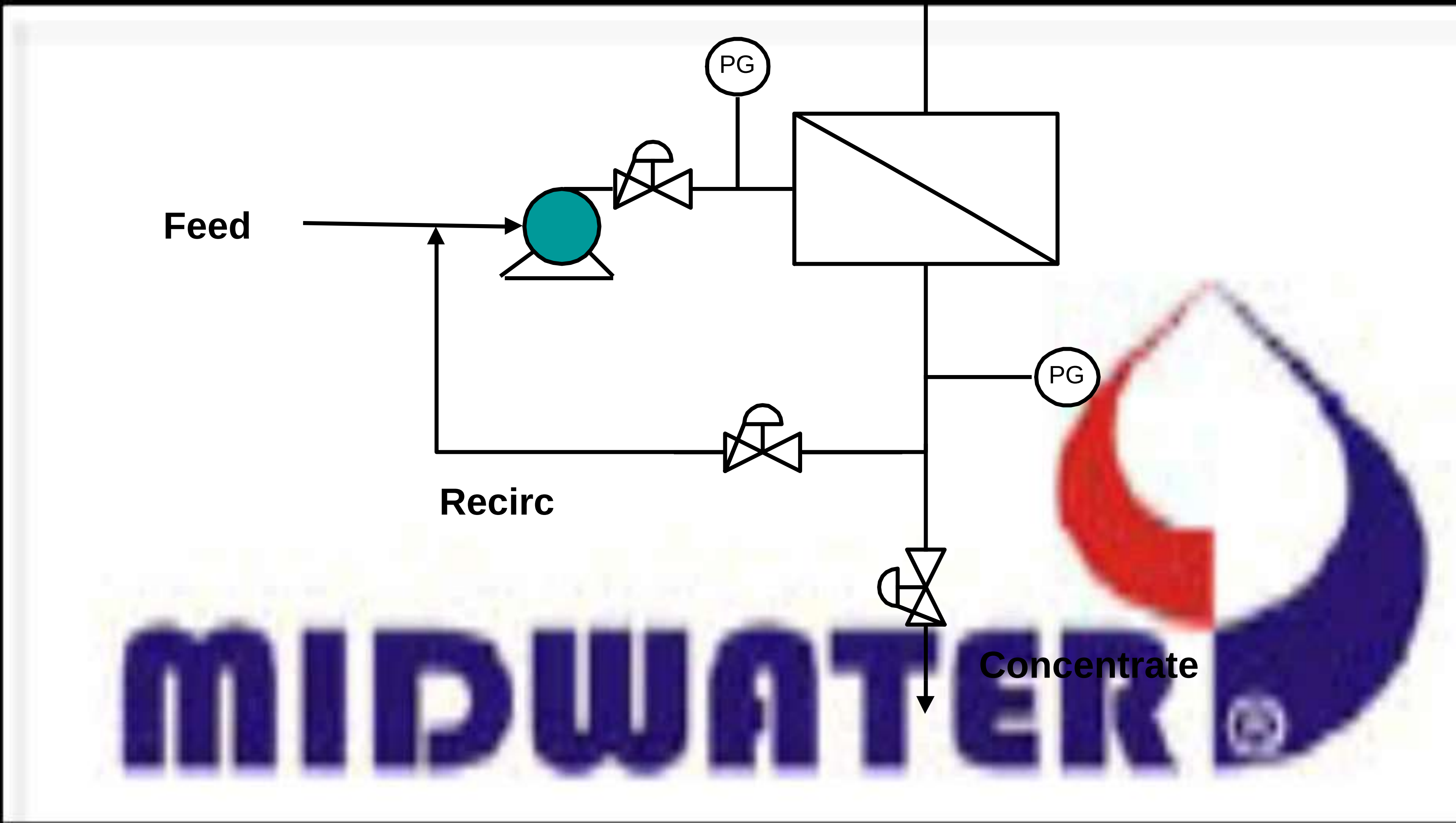
- **Pressure Vessels:** Spiral wound elements are installed in pressure vessels. Up to seven elements can be connected in series in one pressure vessel.

- **Stages:** Pressure vessels are arranged in connected parallel groups with a common feed called Stages.

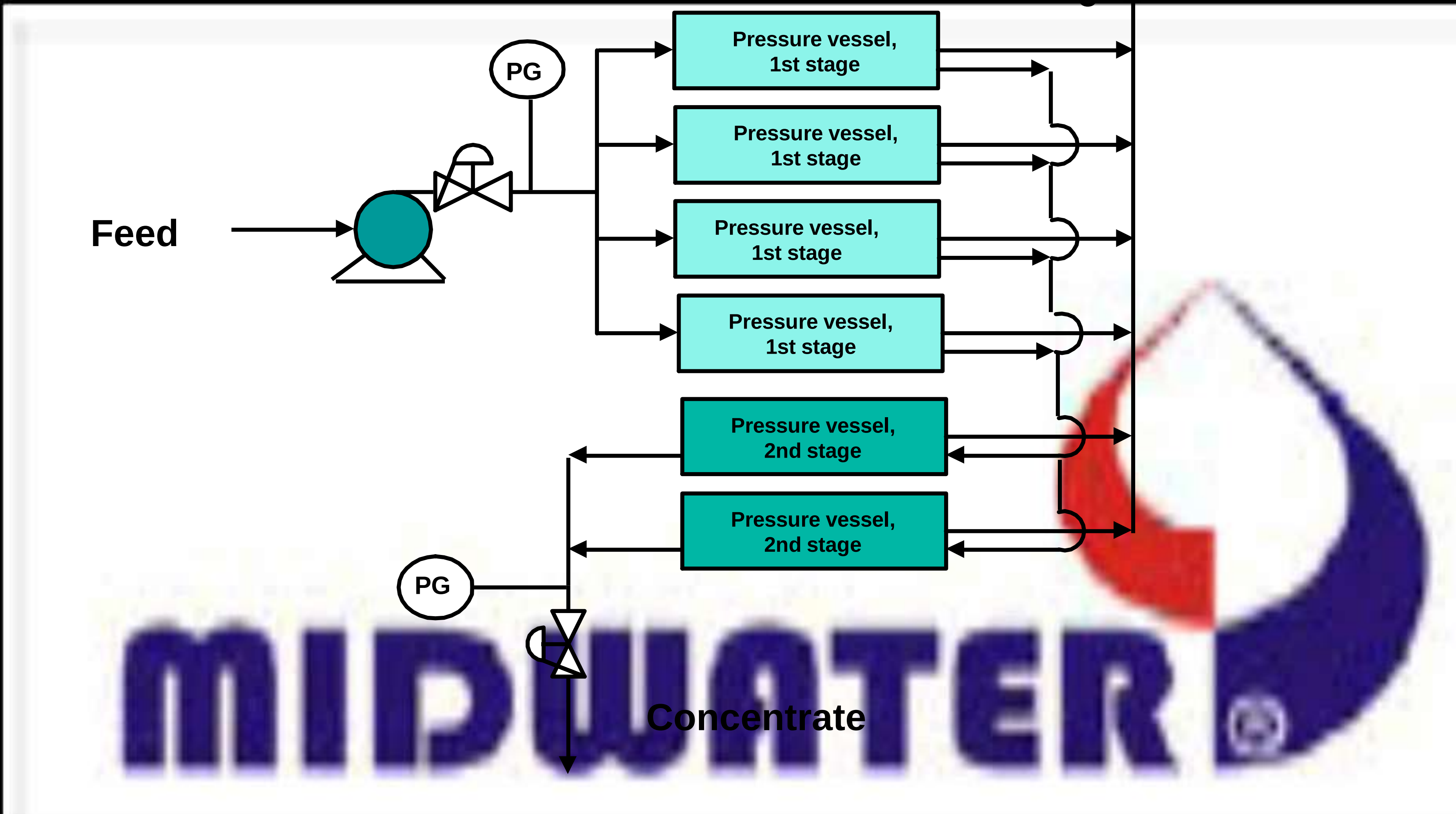
- **Pass:** Stages are connected in series where the concentrate of the 1st stage is collected to become the feed to the next stage to make a Pass.

- **Pyramid Design:** The number of pressure vessels contained between two subsequent stages is about a 2:1 ratio. This is to maintain an optimal feed flow velocity in the element feed channels along the train.

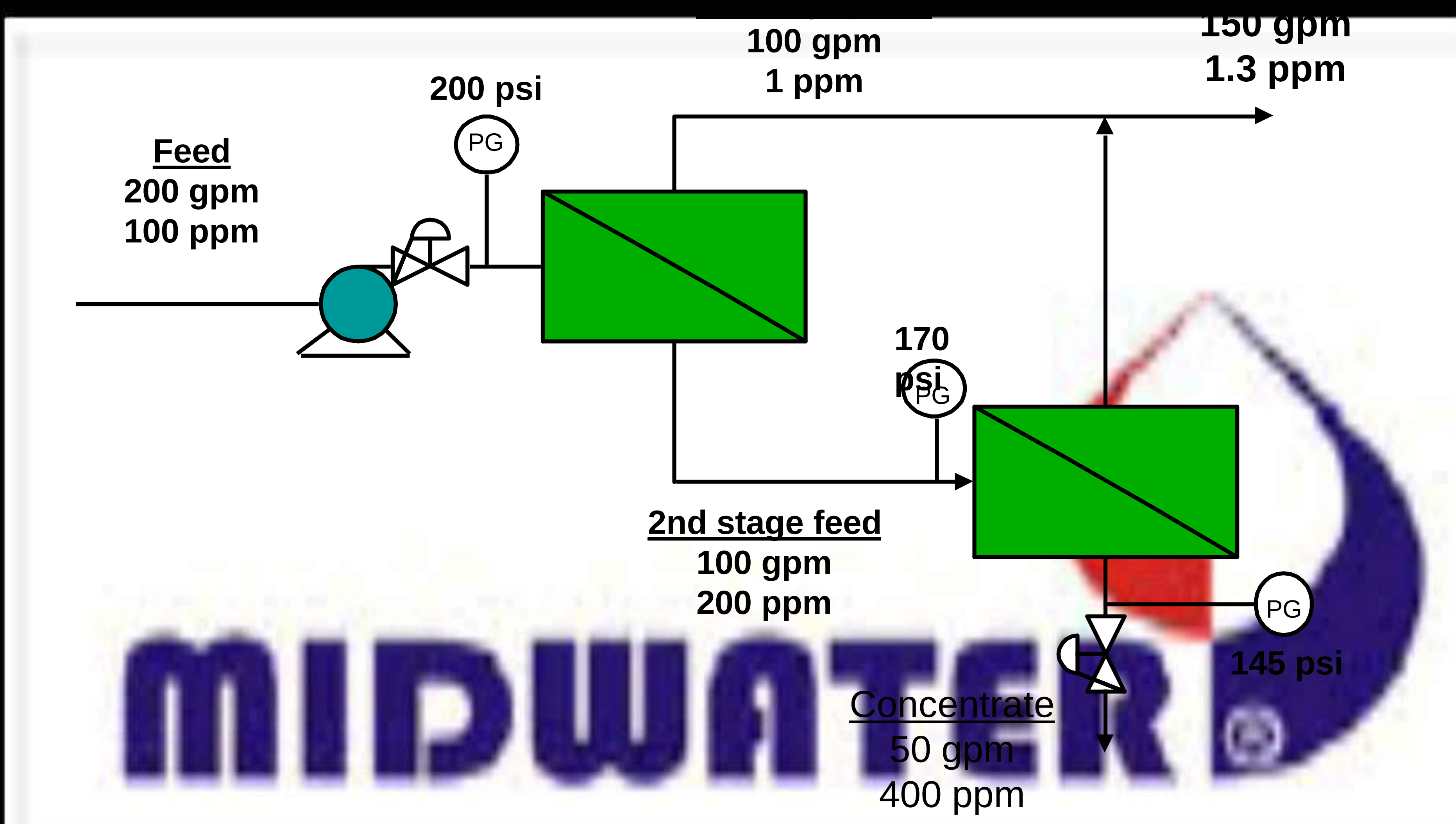
SINGLE STAGE RO WITH CONCENTRATE RECIRCULATION



TWO STAGE RO SYSTEM



TWO STAGE RO SYSTEM AT 75% RECOVERY



Parameters Influence Membranes Efficiencies.

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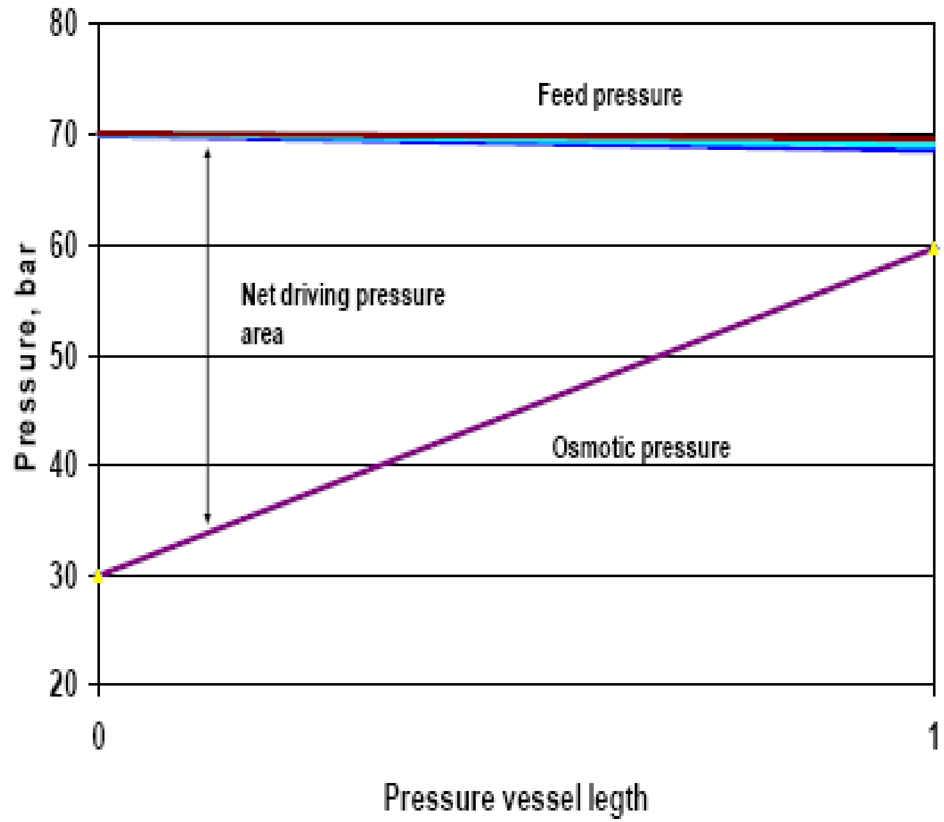
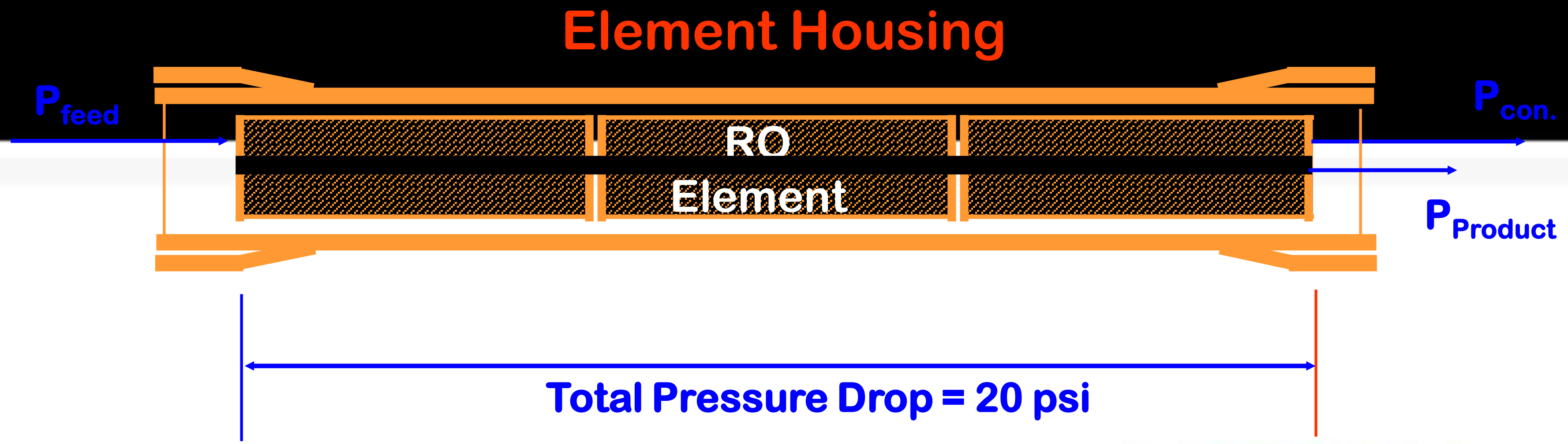
Net Driving Pressure (NDP)

NDP – Net driving pressure :
Driving force of the water transport(Flux) through the membrane.



PRESSURE α PRODUCTIVITY



$$P_{net} = (P_{Feed} - \Delta\pi - \Delta P - P_p)$$

Where: Pnet = Net Driving Pressure

P_{Feed} = Applied Pressure

$\Delta\pi$ = Osmotic Pressure Differential

ΔP = Hydraulic Pressure Losses ($P_{Feed} - P_{con.}$)

$P_{product}$ = Permeate Pressure

- **Water Transport**: The rate of water passage through a semi-permeable membrane is proportional to NDP and is a function of :

  1. **The type of membrane used.**
  2. **NDP (Net Driving Pressure).**

Qw = A x NDP

where: Qw = rate of water flow

A = unique constant for each membrane

NDP = feed psi - osmotic psi - product psi

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- **Salt Transport**: The rate of salt flow across the membrane is proportional to the salt concentration differential and is a function of:

  1. **The type of membrane used.**
  2. **Salt (or TDS) concentration.**

Qs = B x (delta C)

where: Qs = Flow rate of salt thru membrane

B = unique constant for each membrane type

delta C = salt concentration differential across the membrane

RO Salt Rejection

- **RO Permeate Quality is based on:**

  1. The amount of salt that passes through the membrane.
  2. The amount of water that passes through to dilute the salt.

- **% Salt Leakage: (Product TDS / Feed TDS) x 100%**
- **% Salt Rejection: 100% - (% Salt Passage)**

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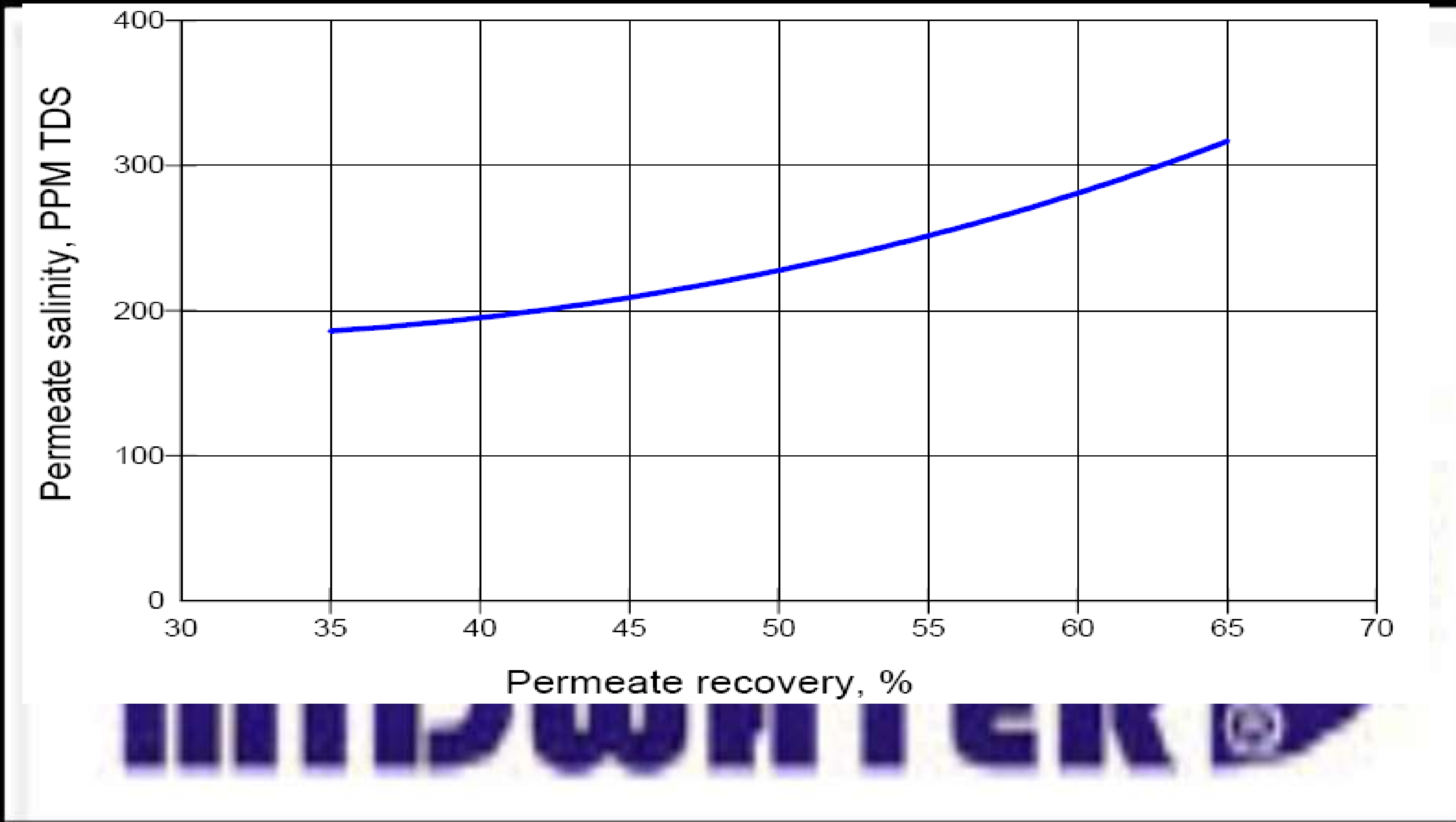
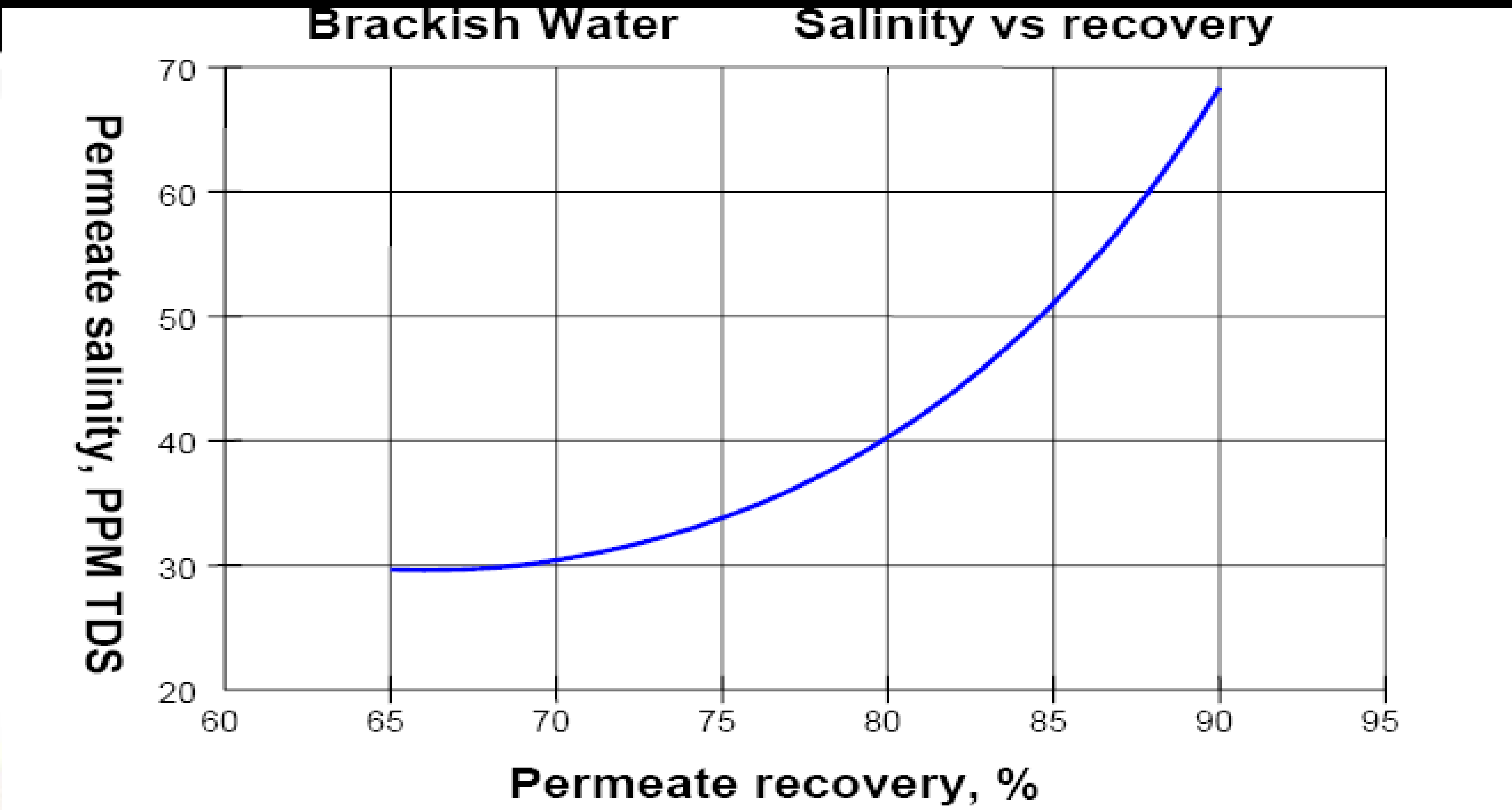
RECOVERY

$$\% \text{ Recovery} = \frac{\text{Permeat Flow Rate}}{\text{Feed Flow Rate}} \text{ X } 100\%$$

At 50 % recovery, reject TDS is 2 times higher than feed TDS
At 67 % recovery, reject TDS is 3 times higher than feed TDS
At 75 % recovery, reject TDS is 4 times higher than feed TDS
At 80 % recovery, reject TDS is 5 times higher than feed TDS
At 90 % recovery, reject TDS is 10 times higher than feed TDS

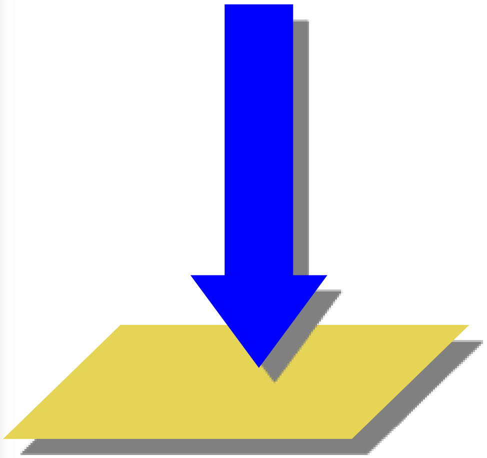
Seawater Salinity versus Recovery




Brackish Water Salinity vs recovery
Permeate salinity, PPM TDS
70
60
50
40
30
20
60
65
70
75
80
85
90
95
Permeate recovery, %

FLUX

FLUX : RATE OF PERMEATE TRANSPORTED PER UNIT OF MEMBRANE AREA.



Surface m2

Flux = Speed Of Filtration

$$\text{FLUX} = \frac{\text{FLOW RATE Of PERMEATE}}{\text{SURFACE OF MEMBRANE}}$$

Unit : $L/h/m^2$ or gallons per square foot per day (gfd)

SELECTING FLUX RATE

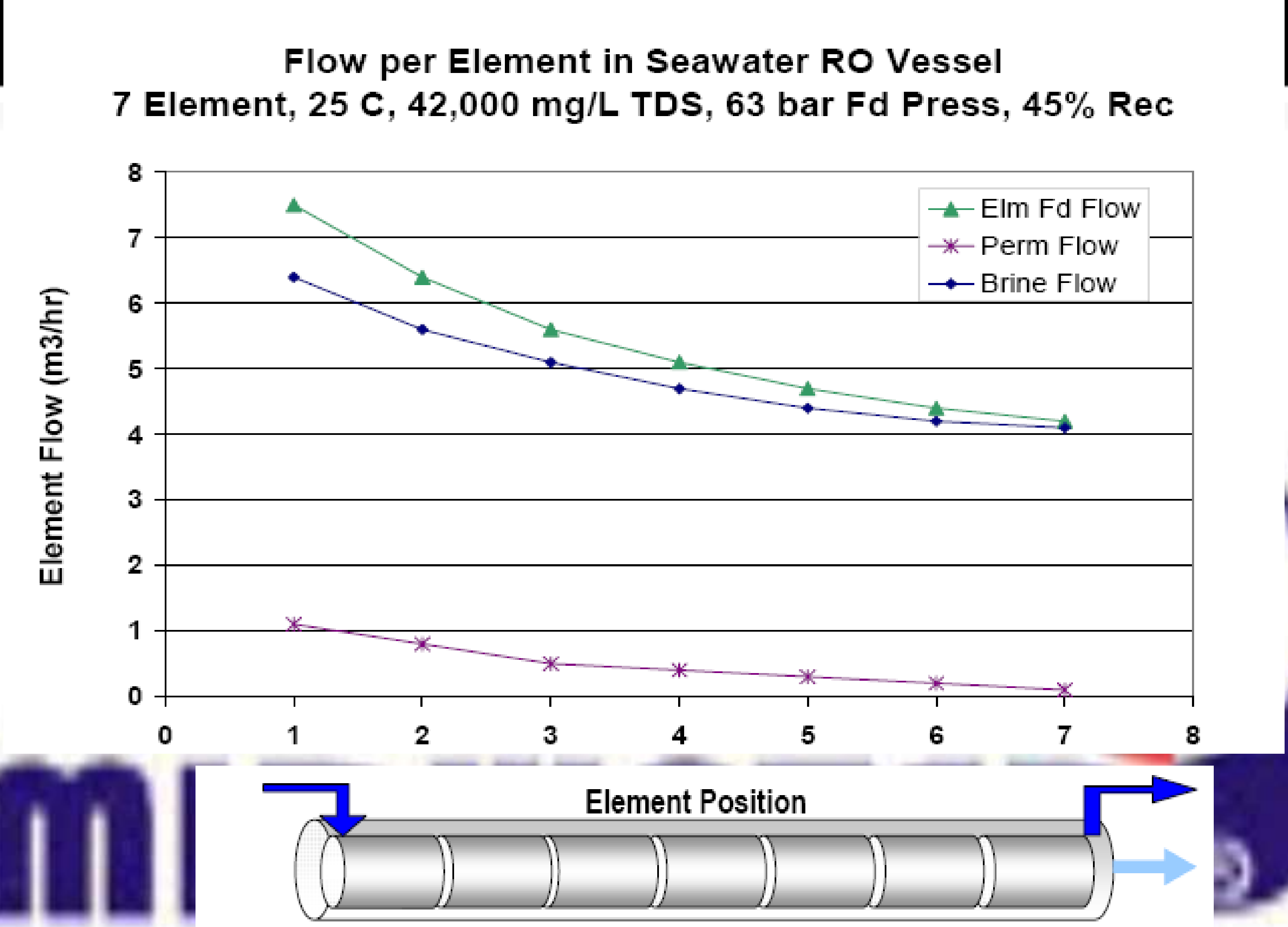
1. Flux rate depends on feed water type and degree of fouling potential.

2. Lead element flux is critical when TOC or particle fouling is likely.

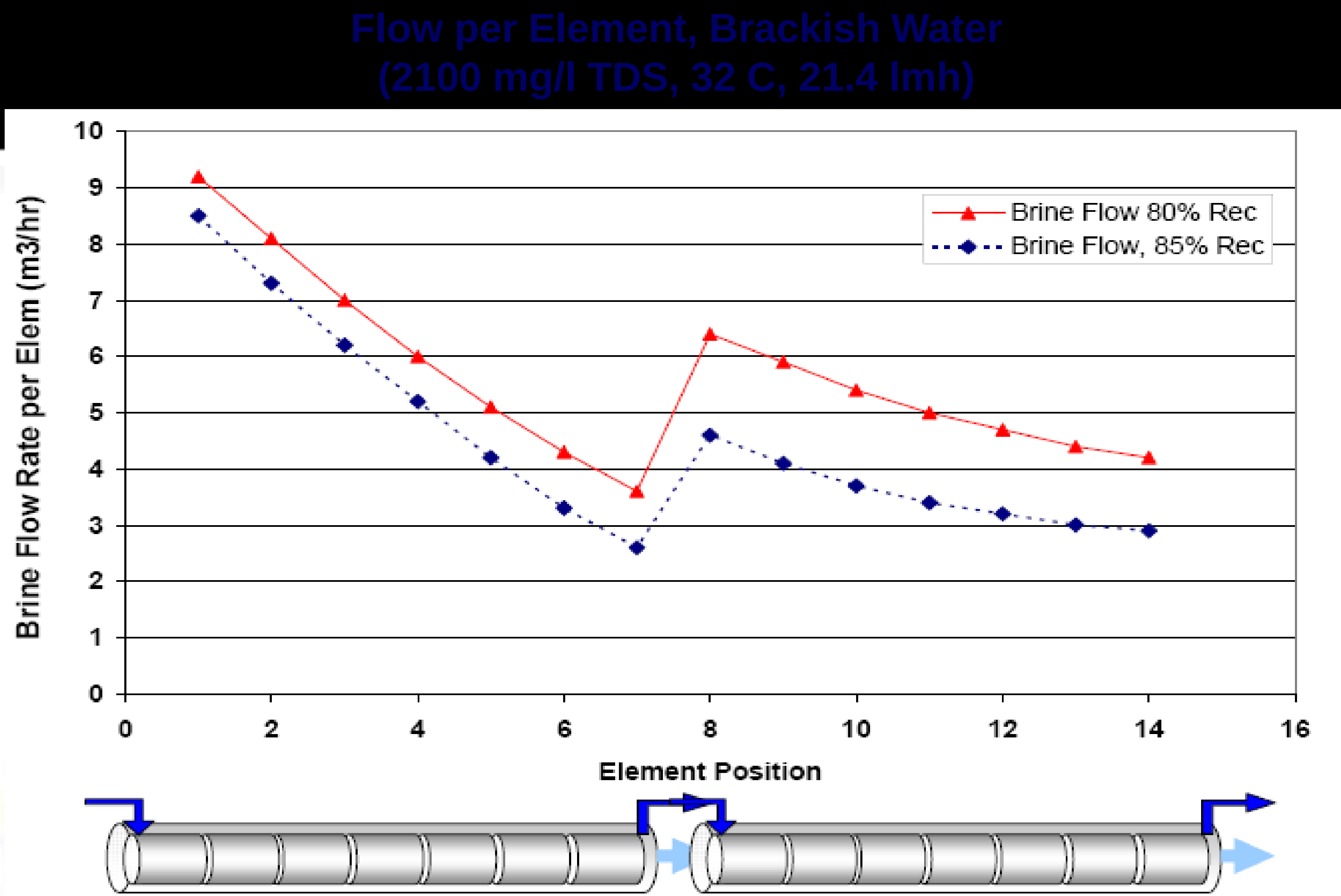
TYPICAL FLUX

Reverse osmosis	Typical flux (l/h/m2)
Sea water (30 000 - 50 000 mg/L)	13-20
Brackish water (100 - 10 000 mg/L)	27-34 - Well water
	20-29 – Surface Water
RO Permeate	36-43

Hydradaulic Flow in SWRO Vessel



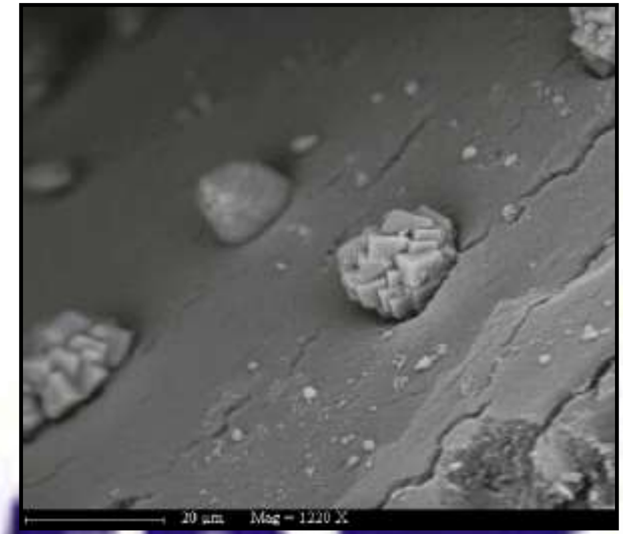
Effect of Recovery on Brine Flow



Factors affecting membrane performance

- CONCENTRATION POLARISATION.

- FOULING.



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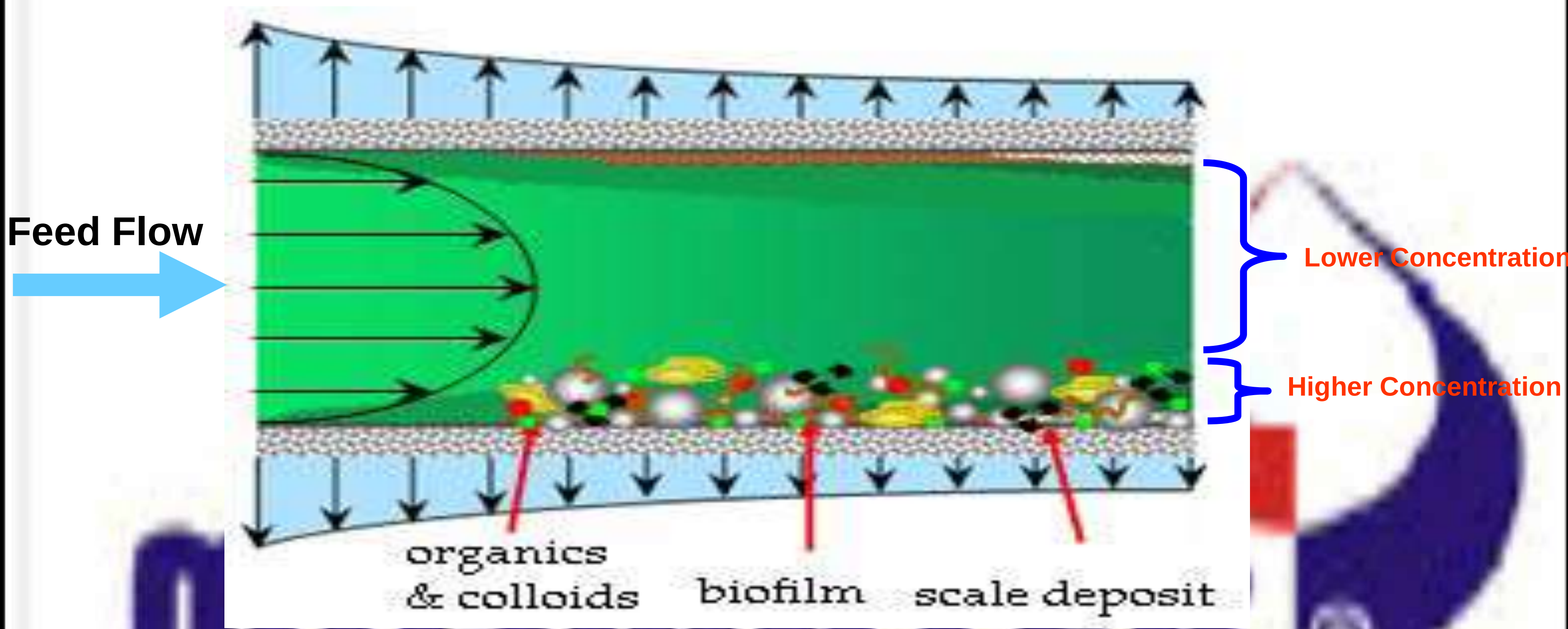
CONCENTRATION POLARIZATION

Concentration Polarization (CP) :

Build-Up of boundary layer of salts near the membrane surface in which the salt concentration there exceeds the salt concentration in the bulk solution.



CONCENTRATION POLARIZATION

Effects of Higher Concentration Polarization

Increases Osmotic Pressure at the membrane surface due to higher TDS concentration. This in turn reduces the permeate flow by reducing the available NDP.

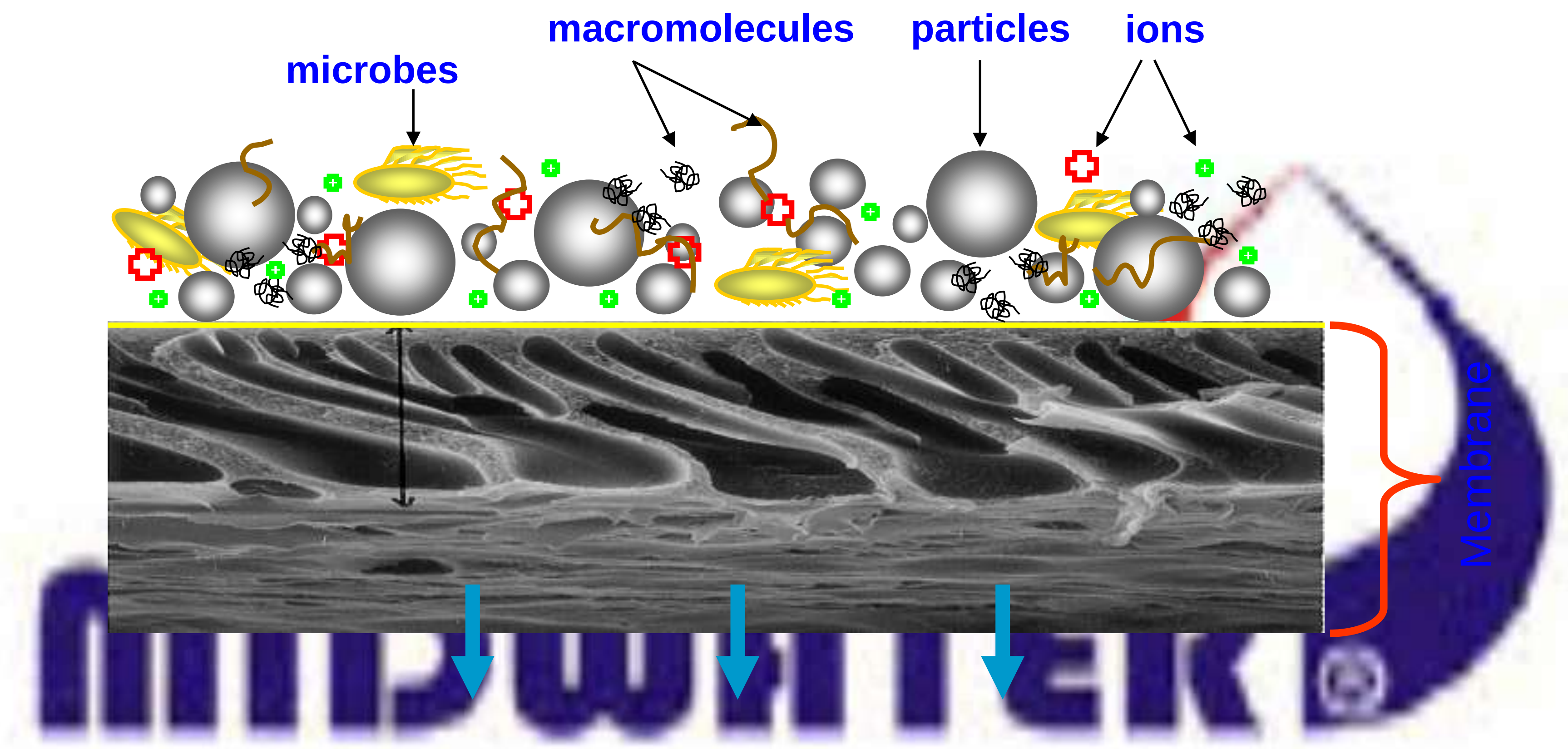
Increases Salt Passage through the membrane due to the higher TDS concentration at the membrane surface.

Increases probability of membrane scaling due to exceeding solubility of sparingly soluble salts at the membrane surface.

FOULING

WHAT IS FOULING ?

ACCUMULATION OF INORGANIC PARTICLES, COLLOIDS, MICROORGANISMS & ORGANIC SLIMES ON SURFACE OR INTO PORES OF THE MEMBRANES.

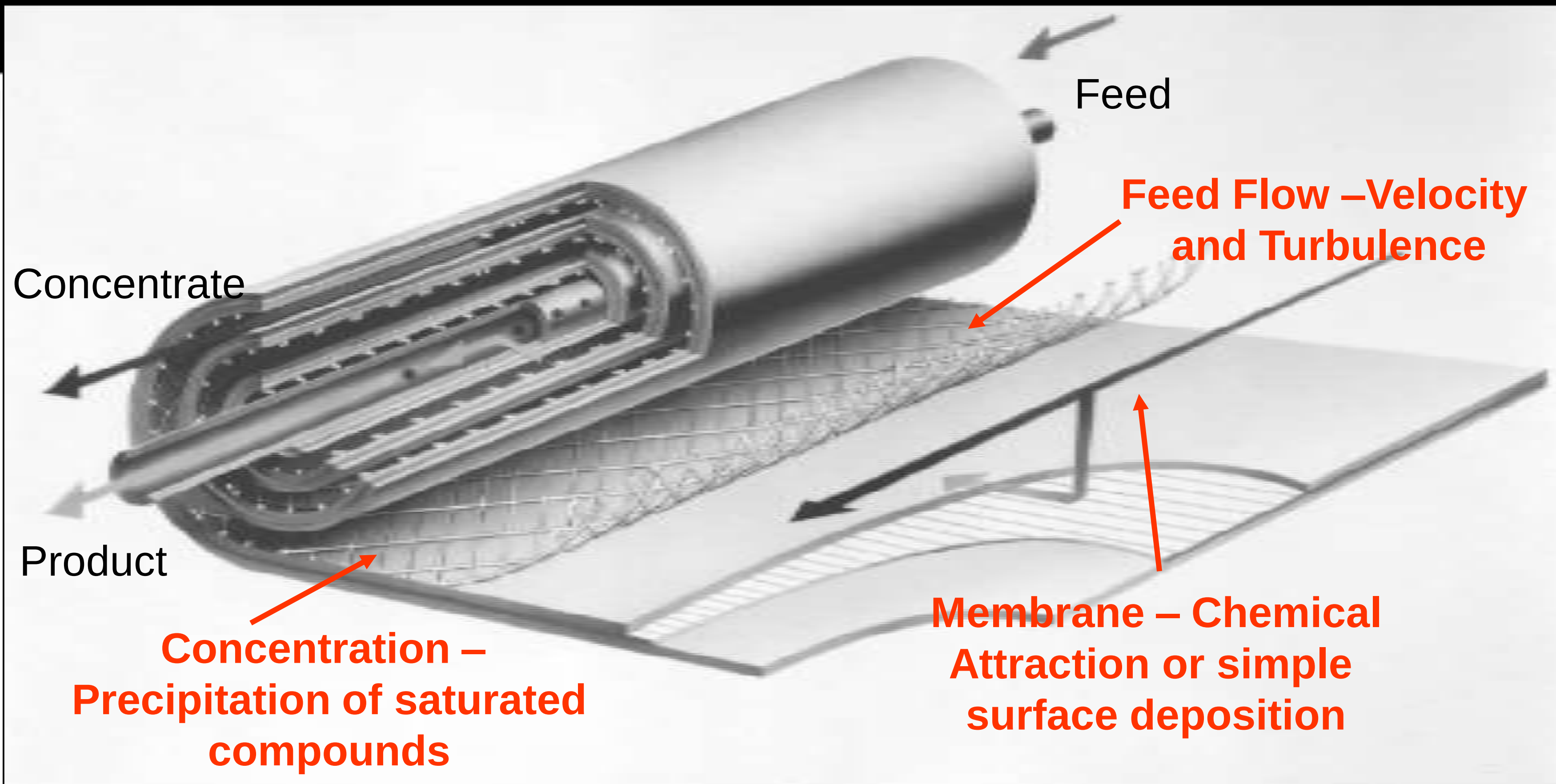


FOULING

Feed Water

Membrane

WHAT IS THE ROOT CAUSE Of MEMBRANE FOULING ?

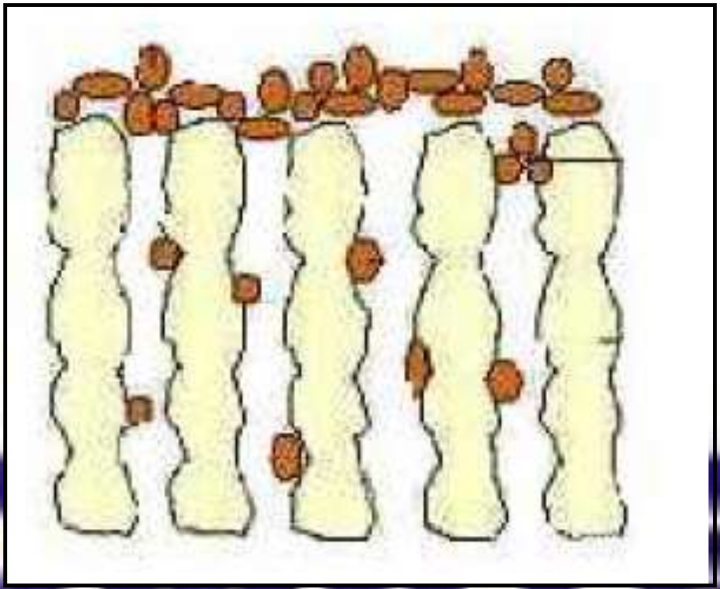


RESULT: Higher Operating Pressure + Loss of Rejection

MEMBRANES FOULING

TWO TYPES

- SURFACE (TEMPORARY) FOULING.
- PORE (PERMANENT) FOULING.



MEMBRANES FOULING

SURFACE (TEMPORARY) FOULING

- FOULANT APPEARS AN EVENLY DEPOSITED LAYER ON THE MEMBRANE SURFACE.
- CAN BE REMOVED BY CLEANING SOLUTION.
- PERMEATION RATE OF MEMBRANE CAN BE REGENERATED BY CLEANING.

MEMBRANES FOULING

PORE (PERMANENT) FOULING

- Particulate matter diffuses into the membrane.
- Could be caused by the poor quality of the feed water.
- Uneven distribution of the foulant and compression of the separation zone.
- Flux cannot be regenerated by cleaning.
- Determines the lifetime of the membrane.

MEMBRANES FOULING

EFFECTS OF FOULING IN REVERSE OSMOSIS PLANTS :

- INCREASE IN FEED PRESSURE.
- INCREASE IN DELTA PRESSURE.
- REDUCTION IN PERMEATE FLOW RATE.
- REDUCTION IN PERMEATE QUALITY.
- INCREASE IN CLEANING FREQUENCY.
- INCREASE IN WATER PRODUCTION COSTS.

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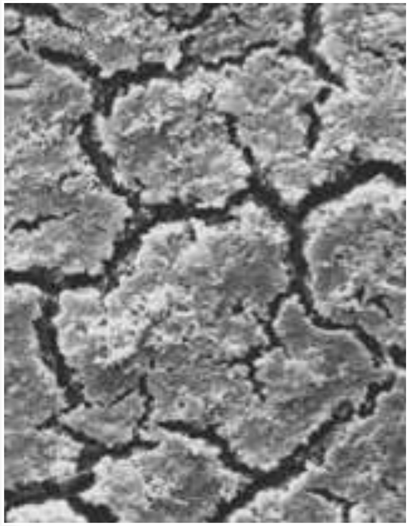
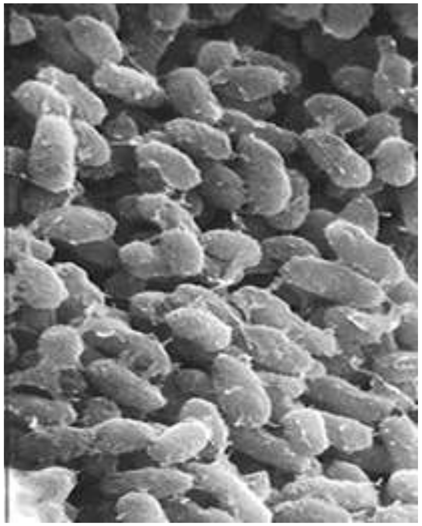
TYPES OF FOULING

Particulates



Biological



Colloidal

Scale

Scanning Electron Micrographs

Fouling Decreases Membrane Productivity

BIOLOGICAL FOULING

BIOLOGICAL FOULING : Loss in productivity throughout the system

Causes…..

- **Microbacterial Contamination Of The Feed Water.**
- **Microbes In The System (e.g. after carbon filter).**
- **System Lay-Up.**
- **Biocide Application.**
- **Contamination In Dosing Tank.**

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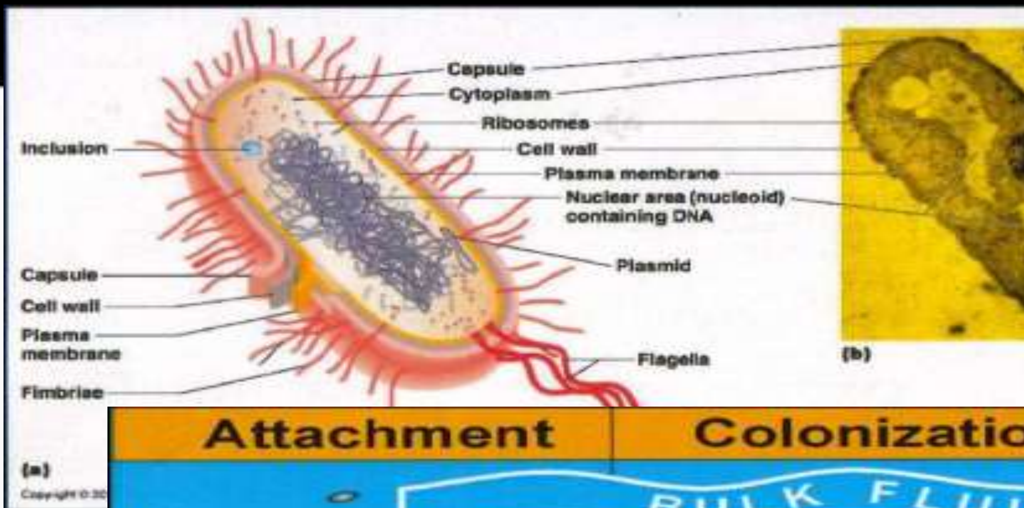
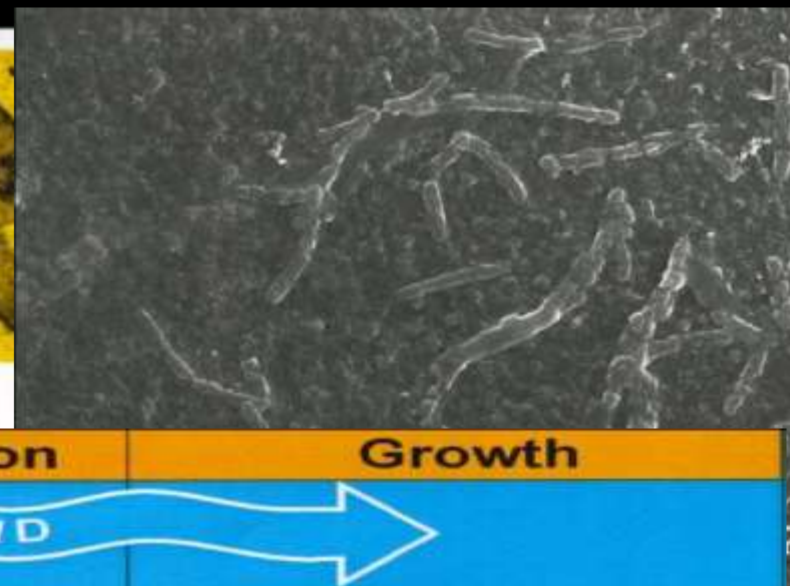
BIOLOGICAL FOULING

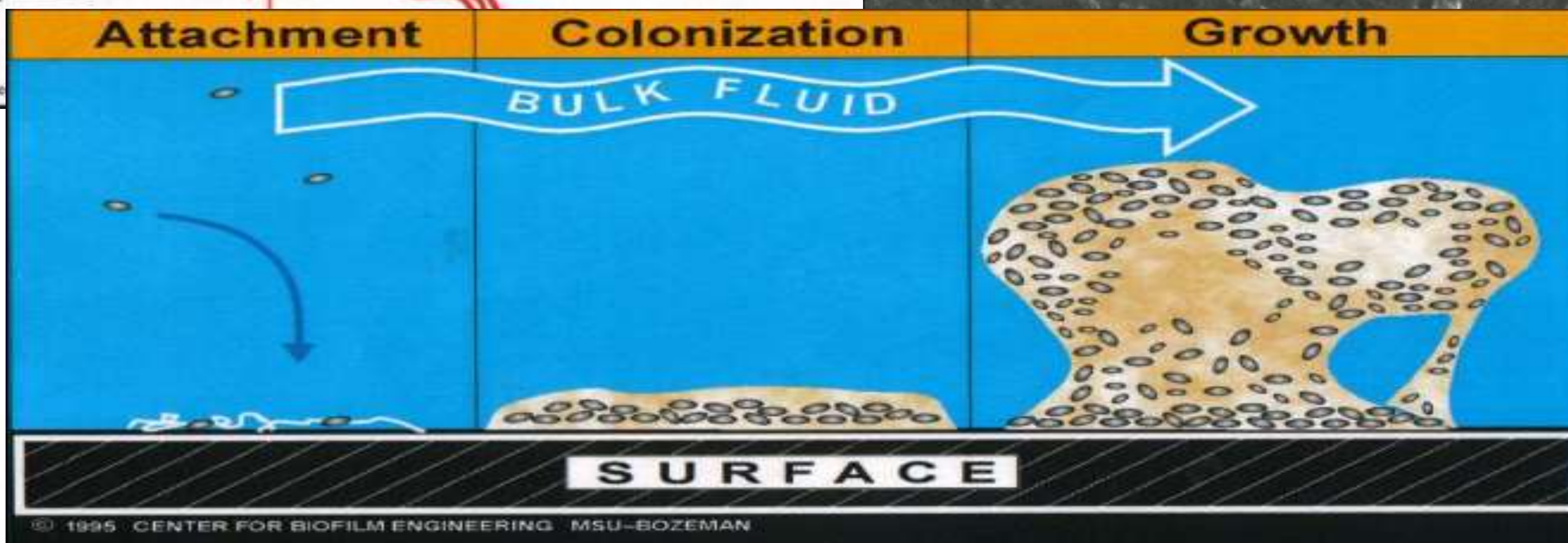
ACCUMULATION OF BIOFILMS OCCURE IN FOUR STAGES :

1. **Adsorption of organic matter resulting in conditioned matter.**
2. **Transport of microbial cells to the conditioned surface.**
3. **Adhesion of microbial cells.**
4. **Biofilm development.**

BIOLOGICAL FOULING







BIOLOGICAL FOULING

BIOFOULED MEMBRANE

BIOLOGICAL FOULING

How Can I Reduce Fouling in My RO System ?

- **Identify Bio-Foulant and Eliminate Source.**
- **Effective Design Of Pre-Treatment System.**
- **Regular Disinfections/Sanitizing Of System.**
- **Frequency Of Biocide Application.**

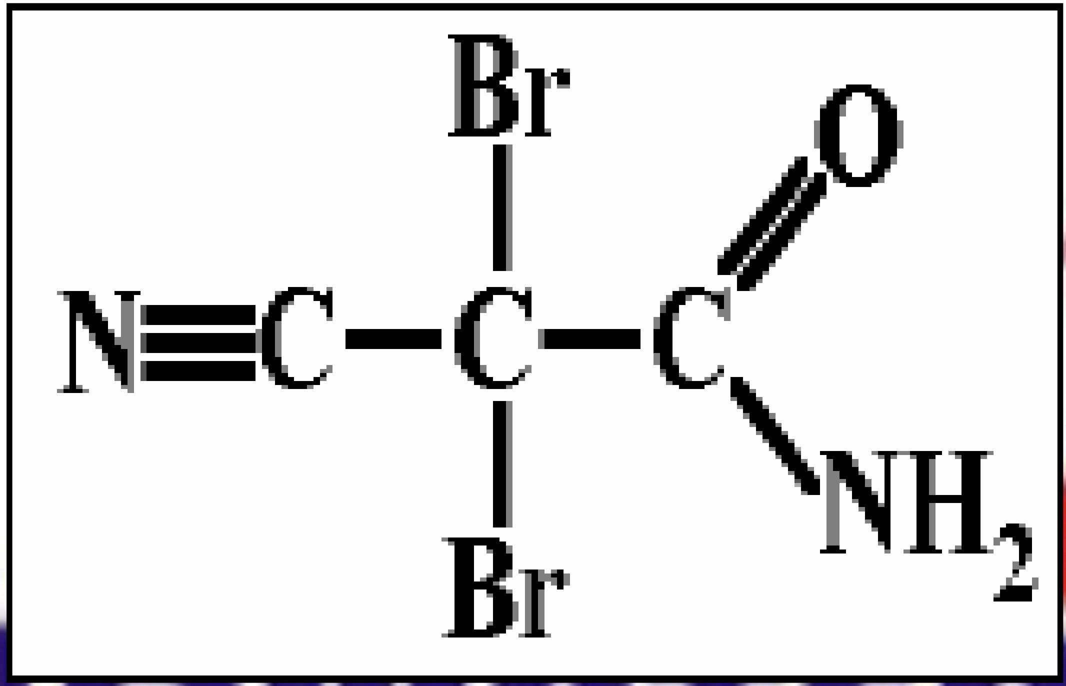
Chemical Prevention of Biofouling……

- **HYDREX™ 4202**
- **HYDREX ™ 4201**

BIOLOGICAL FOULING

PRODUCT : HYDREX™ 4202

Based on DBNPA (2,2, DIBROMO-3-NITRILO-PROPRIONAMIDE).



BIOLOGICAL FOULING

PRODUCT : HYDREX™ 4202

Characteristics:

- **Compatible with the membrane.**
- **Non- Oxidizing Biocide.**
- **Fast acting.**
- **Cost effective .**

Dosage Rate : Depends on the severity of the biological fouling.

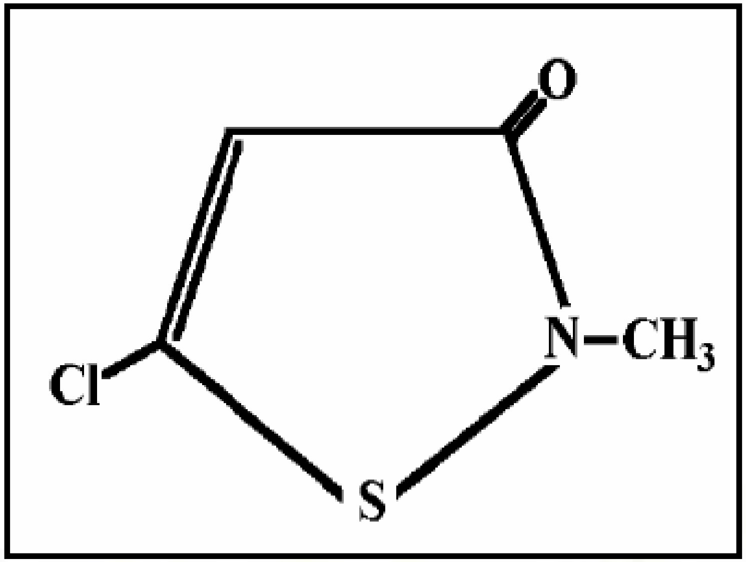
- **Shock Dose** : 10 – 30 ppm for 30 minutes to 3 hours every 5 days.
- **Continuous dose** : 0.5 to 1 ppm
- **CIP** : 100-200 ppm of active ingredient for 1 hour (keep pH neutral)

During shock dosing: Permeate should be dumped if it is for a potable water system.

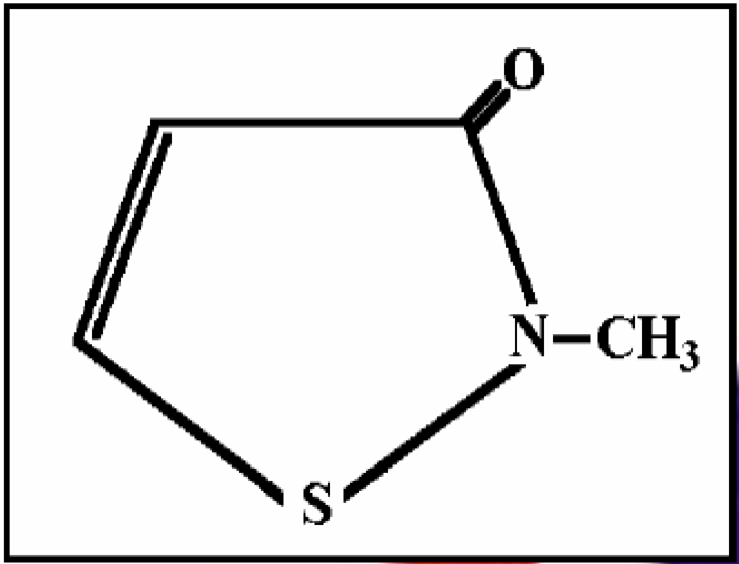
BIOLOGICAL FOULING

PRODUCT : HYDREX™ 4201

Based on :



5-chloro-2-methyl-4-isothiazolin-3-one



2-methyl-4-isothiazolin-3-one

BIOLOGICAL FOULING

PRODUCT : HYDREX™ 4201

- 4 HOURS OF CONTACT TIME (OR MORE).
- BROAD SPECTRUM BIOSTATIC AGENT.
- TARGET: AEROBIC AND ANAEROBIC BACTERIA, FUNGI, AND ALGAE.
- PH RANGE: 6 - 9

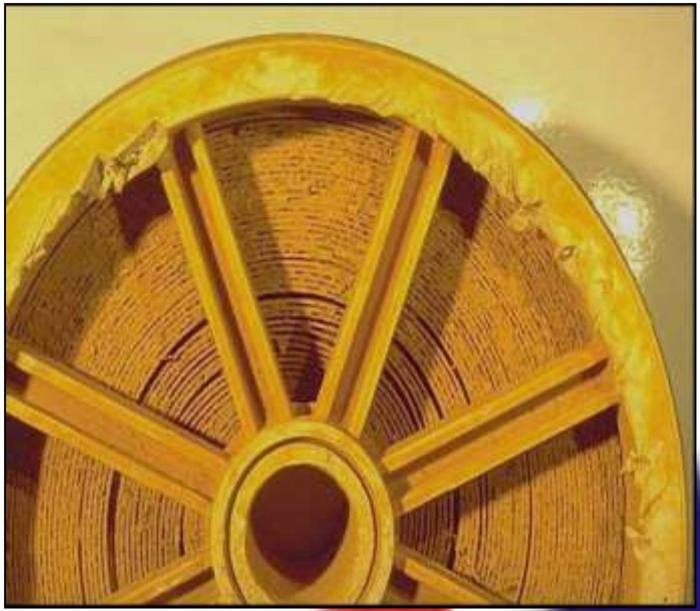
MIDWATER®

COLLOIDAL FOULING

COLLOIDAL FOULING . Fouling of Front End Of System

Causes…….

- Organic Matter.
- Silica.
- Iron Oxide.



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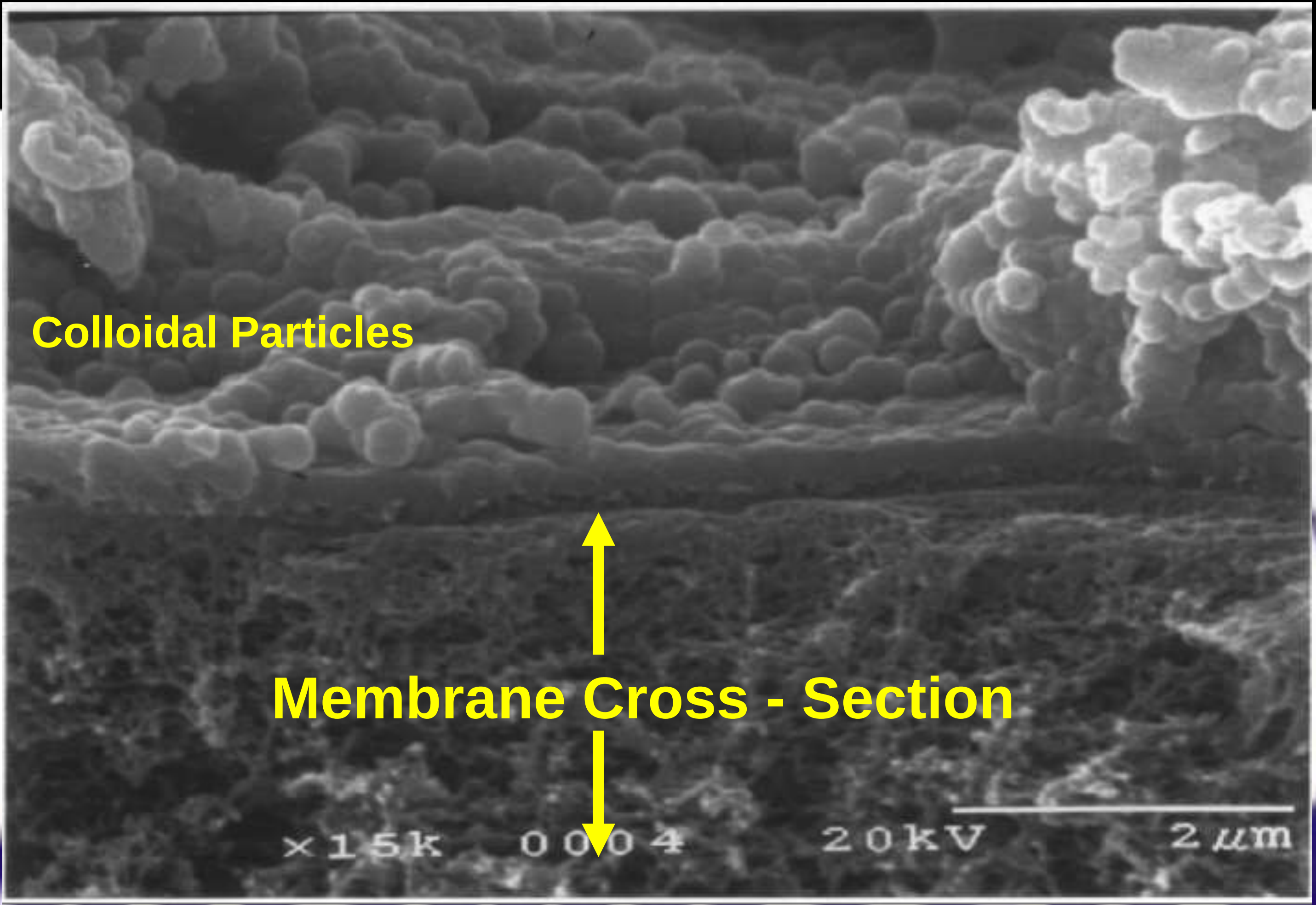
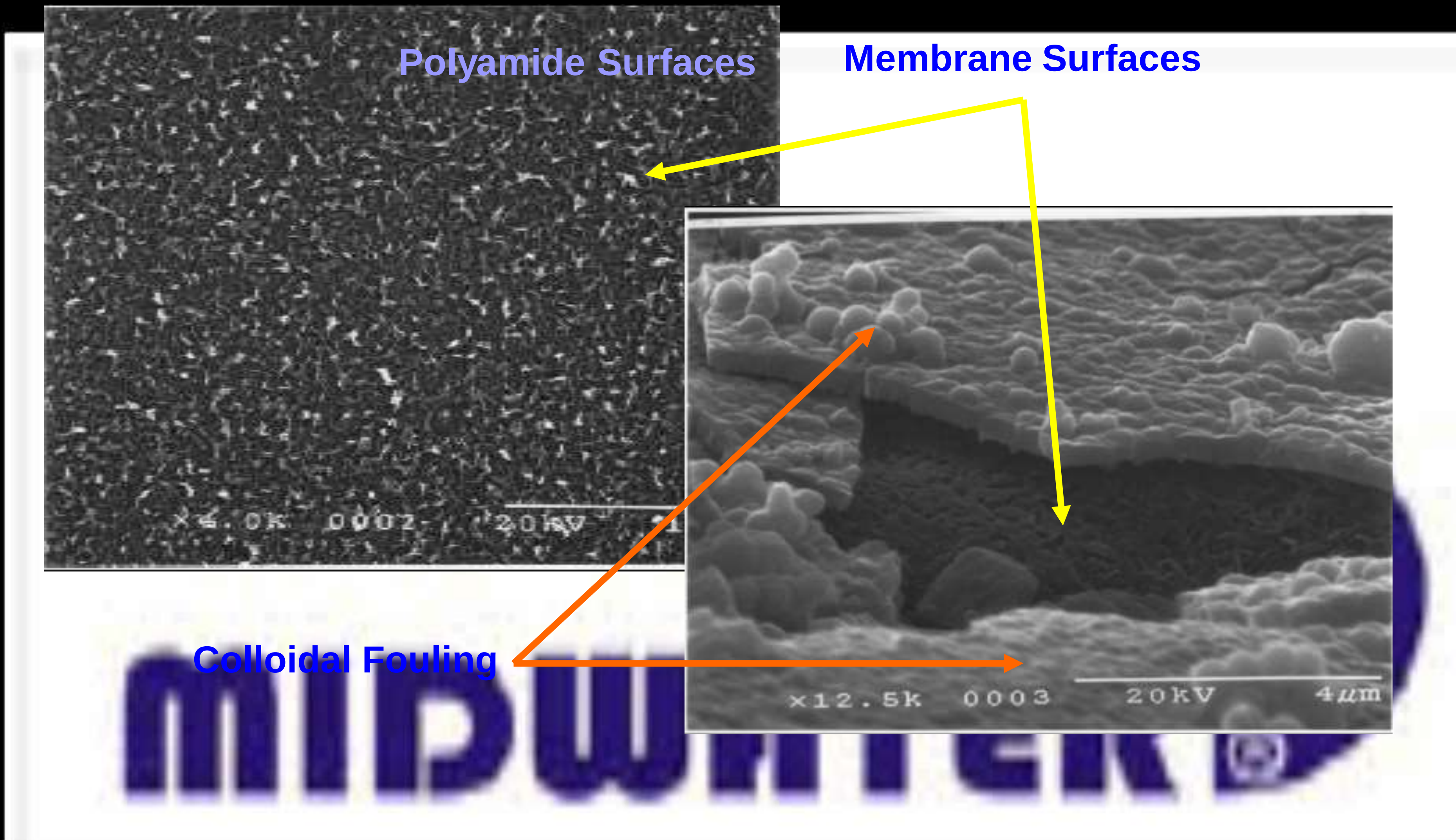
COLLOIDAL FOULING



Colloidal Debris on Membrane Surface

COLLOIDAL FOULING



COLLOIDAL FOULING

FOULANT : IRON OXIDE :

Fe (III)

Iron is dissolved in water as Fe^{+2}

$$4Fe^{+2} + O_2 + 10H_2O \longrightarrow 4Fe(OH)_3\downarrow + 8H^+$$

- **1 mg Fe^{+2} needs 0.14 mg O_2**

Solutions….

- **Pre-Chlorination to enhance oxidation of Fe^{+2}.**
- **Aeration followed by Filtration.**

COLLOIDAL FOULING

FOULANT : SILICA

Fouling of membrane due to Silica deposition occurs due to the following factors:

- **High silica concentration in the feed/brine water (Super saturation).**
- **Conc. polarization next to membrane surface.**
- **Presence of metal ions and silicate formation at low pH.**

Solutions….

- **HYDREX^{TM} Antiscalants (HYDREX 4109).**
- **Reducing Recovery.**
- **Lime Softening.**
- **PH & TEMP. control.**

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COLLOIDAL FOULING

How Can I Reduce Colloidal Fouling in My RO System ?

EFFECTIVE DESIGN OF PRE-TREATMENT SYSTEM.

- SDI (< 3 preferred).
- Turbidity (< 0.1 preferred).
- Particle Counts (<100 of 2 µm particles/ml).

- **FILTRATION SYSTEM MAY NEED ADJUSTMENT.**
  - Media Selection.
  - Coagulant Optimization.
  - Filtration Velocities.

  - Membrane Pretreatment.
    MF is generally 0.1-0.2 micron.
    UF is generally 0.02 micron.

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PARTICULATE FOULING

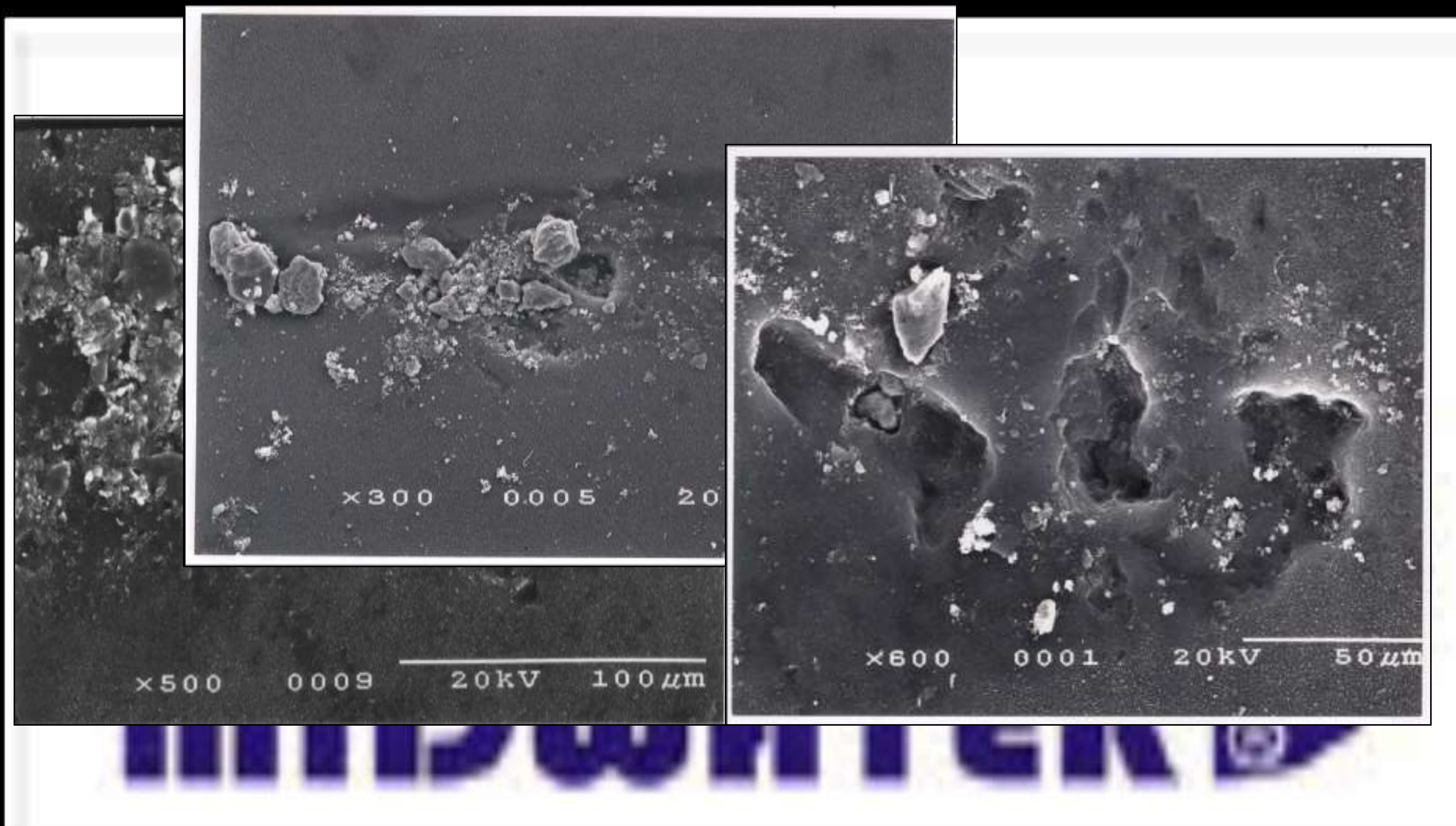
PARTICULATE FOULING : Front End Fouling

Causes ……

- **Suspended Solids.**
- **Silts.**
- **Filter media.**
- **Corrosion Debris.**
- **Foreign objects.**

PARTICULATE FOULING

Surface Damage Caused By
Particulate Matter on RO surface



PARTICULATE FOULING

Particulate on Spiral Wound Element

PARTICULATE FOULING

Solution…….

- **Identify Foulant.**
- **Effective Design Of Pre-Treatment System.**
- **Sedimentation.**
- **Filtration (cartridge, multi-media etc).**
- **Good maintenance schedule.**
- **Use effective antiscalant/antifoulant - HYDREX™**

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Expected average raw water quality from well , surface intake and secondary effluent

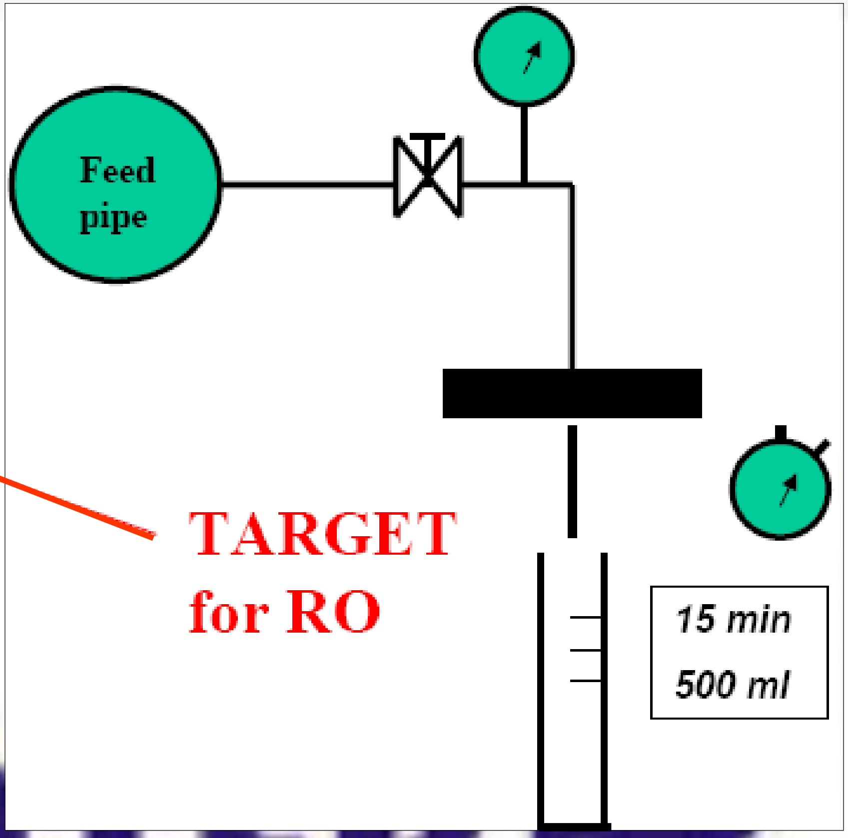
Quality Parameter	Well Water	Surface Water (Sea Water)	Secondary Effluent
Turbidity, NTU	<0.1	< 2	< 2
SDI	< 2	6 - 12	6 –12
Suspended Solids	< 1	< 5	< 20
TOC , ppm	< 3	< 5	< 20
Scaling Potential	Low to High	Low	Low (Except in presence of high concentration of phosphate

Particles and bacteria cause rapid fouling of RO membranes

Measurement Of Feed Water For SWRO PLANT
SDI

Silt Density index : $SDI = 100*(1 - t_0/t_{15})/15$

t_0	t_{15}	SDI (15 min)
18	22	1.2
20	33	2.6
26	73	4.3
46	50	0.5 ?



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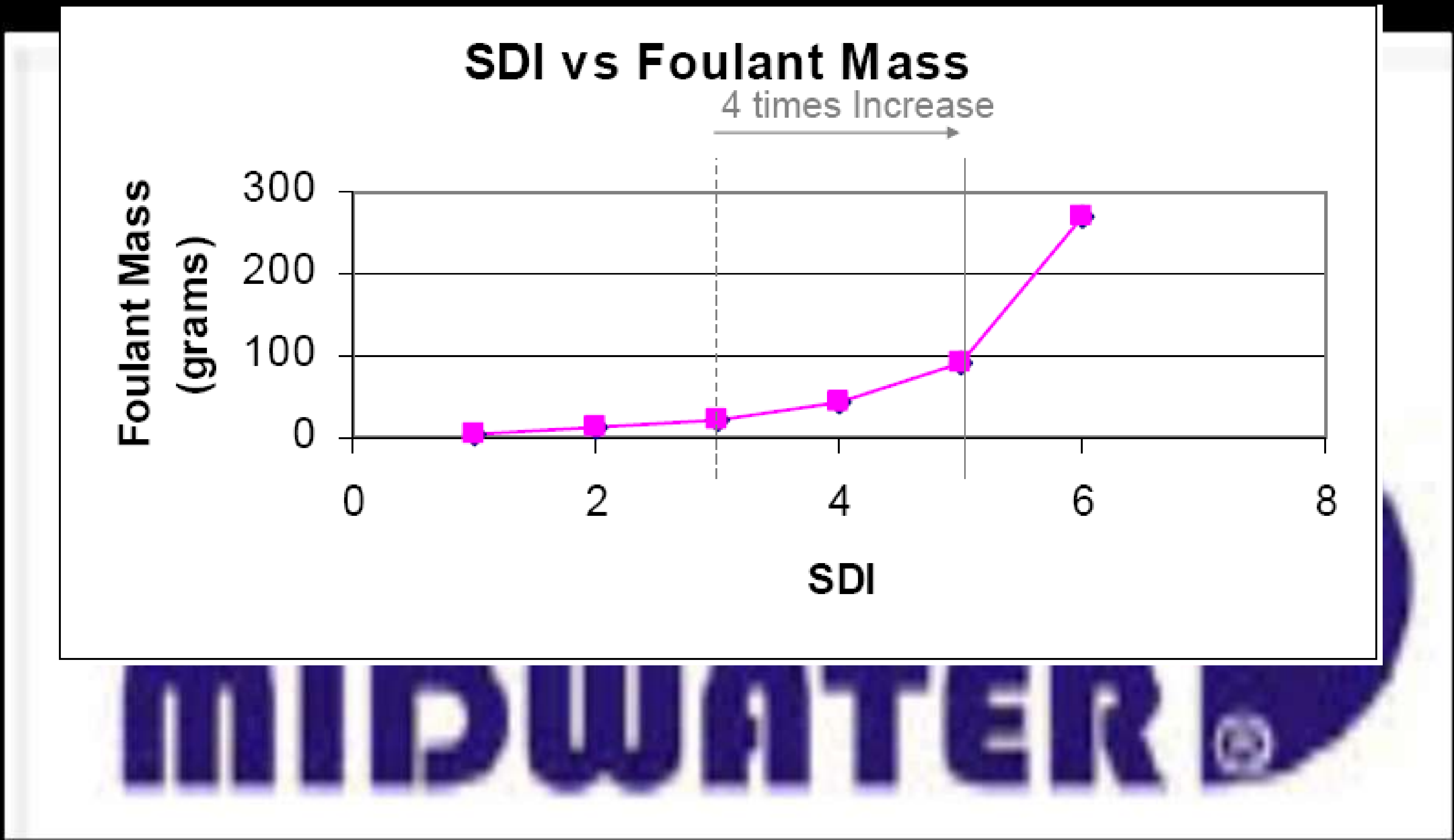
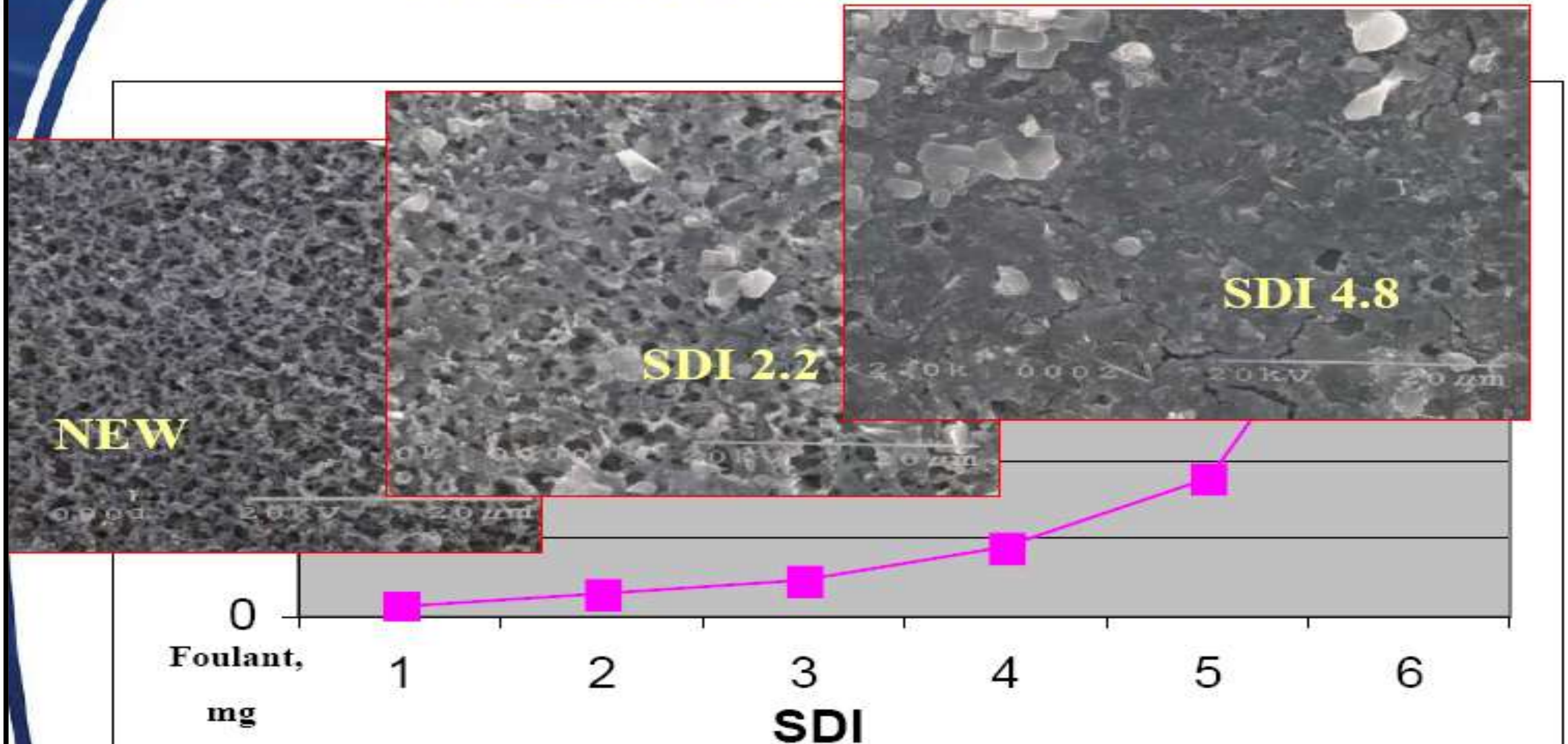
Importance of Low SDI



Amount of Foulant vs SDI



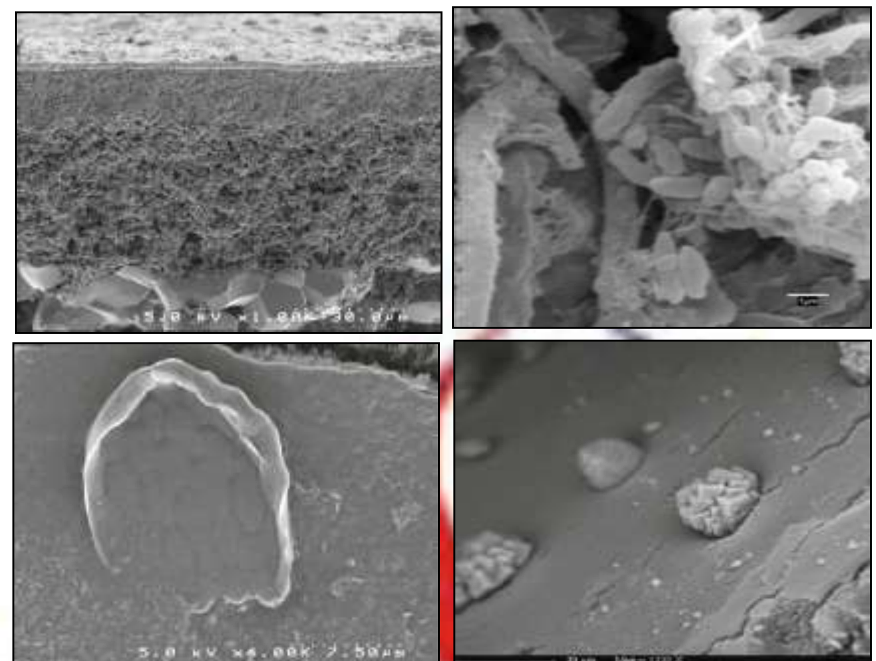
CHEMICAL FOULING (SCALE)

Causes……

- Inorganic Salt Solubility Exceeded in Brine.

Examples :

- Calcium Carbonate. $CaCO_3$
- Calcium Sulphate. $CaSO_4$
- Silica.SiO_4
- Barium Sulphate. $BaSO_4$
- Strontium Sulphate. $SrSO_4$
- Calcium Flouride. CaF



- Structure of fouling deposit
- Composition of fouling deposit

CHEMICAL FOULING (SCALE)

SOLUBILITIES OF SALTS IN PURE WATER , GRAM/LITRE @ 18 ^{0}C

	Na^{+}	Ca^{+2}	Mg^{+2}	K^{-}	Ba^{+2}	Sr^{+2}
Cl	360	730	560	330	370	510
SO_4^{-2}	170	2	350	110	0.002	0.11
NO_3^{-}	840	1220	740	300	90	70
CO_3^{-2}	190	0.013	1	1080	0.02	0.011
F^{-}	45	0.016	0.076	930	1.6	0.1

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CHEMICAL FOULING (SCALE)

CALCIUM CARBONATE SCALE:

Common method to judge the scale potential of $CaCO_3$:

1. Langeliar Saturation Index :

$LSI = PH_{\text{Brine water}} - PH_S$ **(TDS < 10,000 mg/L)**

PH_S = pH @ which concentrate stream is saturated with $CaCO_3$

PH_s = pCa + palk + C

where
PCa = calcium hardness factor (expressed as ppm $CaCO_3$,)
Palk = M alkalinity factor (expressed as ppm $CaCO_3$,)
C = total solids (expressed as ppm at the temperature of the water)

CHEMICAL FOULING (SCALE)

Equation # 1 $$(CO_2) = \frac{(H^+) \times (TA)}{K_1 \times [1 + (2K_2/(H^+))]}$$

Equation # 2 $$(HCO_3^-) = \frac{(TA)}{1 + (2K_2/(H^+))}$$

Equation # 3 $$(CO_3^{-2}) = \frac{(TA)}{2 + ((H^+)/K_2)}$$

Equation # 4 $$PK_1 = 6.41 – 1.559 \times 10^{-3} T + 3.52 \times 10^{-6} T^2 – 3.07 \times 10^{-5} P - 0.4772 I^P + 0.1108 I$$

Equation # 5 $$PK_2 = 10.61 – 4.97 \times 10^{-3} T + 1.331 \times 10^{-5} T^2 – 2.624 \times 10^{-5} P - 1.166 I^P + 0.3488 I$$

TA : Total Alkalinity , Equivelant/Liter.
T : Temperature , I : Ionic Strength
K_1, K_2 : First & Second ionization constants of Carbonic Acid
P : Pressure , psig
( ) : Moles/Liter of indicated ion.
PK : Negative Log of K

CHEMICAL FOULING (SCALE)

Equation # 6 $$PH = pK_1 + Log \frac{(HCO_3^-)}{CO_2}$$

Equation # 7 $$PH = pK_2 + Log \frac{(CO_3^{-2})}{(HCO_3^-)}$$

Equation # 8 $$PH = (pK_1 + PK_2) /2$$

TA : Total Alkalinity , Equivelant/Liter.
T : Temperature , I : Ionic Strength
K_1, K_2 : First & Second ionization constants of Carbonic Acid
P : Pressure , psig
( ) : Moles/Liter of indicated ion.
PK : Negative Log of K

CHEMICAL FOULING (SCALE)

SULPHATE SALTS :

$CaSO_4$, $BaSO_4$, $SrSO_4$

To avoid precipitation of these salts :

$$IP_b < Ksp$$

IP_b : Ion product of brine water
Ksp : Solubility product

CHEMICAL FOULING (SCALE)

To Calculate the ion product of $CaSO_4$ in concentrate stream :

THE ION PRODUCT IP OF $CaSO_4$:

$IP_{Feed} = [Ca]^2[So_4]^2$

where: [Ca] , $[So_4]$ = molal concentrations (Mol/L)

To convert concentration of ion from (mg/ltr) to (Mol/L) :

$$[Ca] = \frac{Ca\ (mg/Ltr)}{1000\ M.Weight - Ca}$$

$$[SO_4] = \frac{SO_4\ (mg/Ltr)}{1000\ M.Weight - SO_4}$$

$$IP_{Brine} = IP_{feed} \times (1/1-R)^2$$

CHEMICAL FOULING (SCALE)

If $IP_{Brine} > Ksp$, $CaSO_4$ scaling can occur

$IP_{Brine} < Ksp$, No Scale

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CHEMICAL FOULING (SCALE)

Recovery Limitations: Scaling

	Saturation Limits:	HYDREX™ Antiscalants
$CaSO_4$	230 %	350%
$SrSO_4$	800 %	3500%
$BaSO_4$	6000 %	12000%
SiO_2	100 %	240%
$CaCO_3$	0	2.8
CaF_2		10000%

CHEMICAL FOULING SCALE FORMATION

PRECIPITATION (CRYSTALLISATION) OF SCALE

THE SEQUENCE OF EVENTS THAT LEADS TO THE CRYSTALLISATION OF A SALT MAY BE DEFINED AS :

Water & Soluble Minerals → SOLUBALISATION → SUPERSATURATION → NUCLEATION → CRYSTAL GROWTH → SCALE

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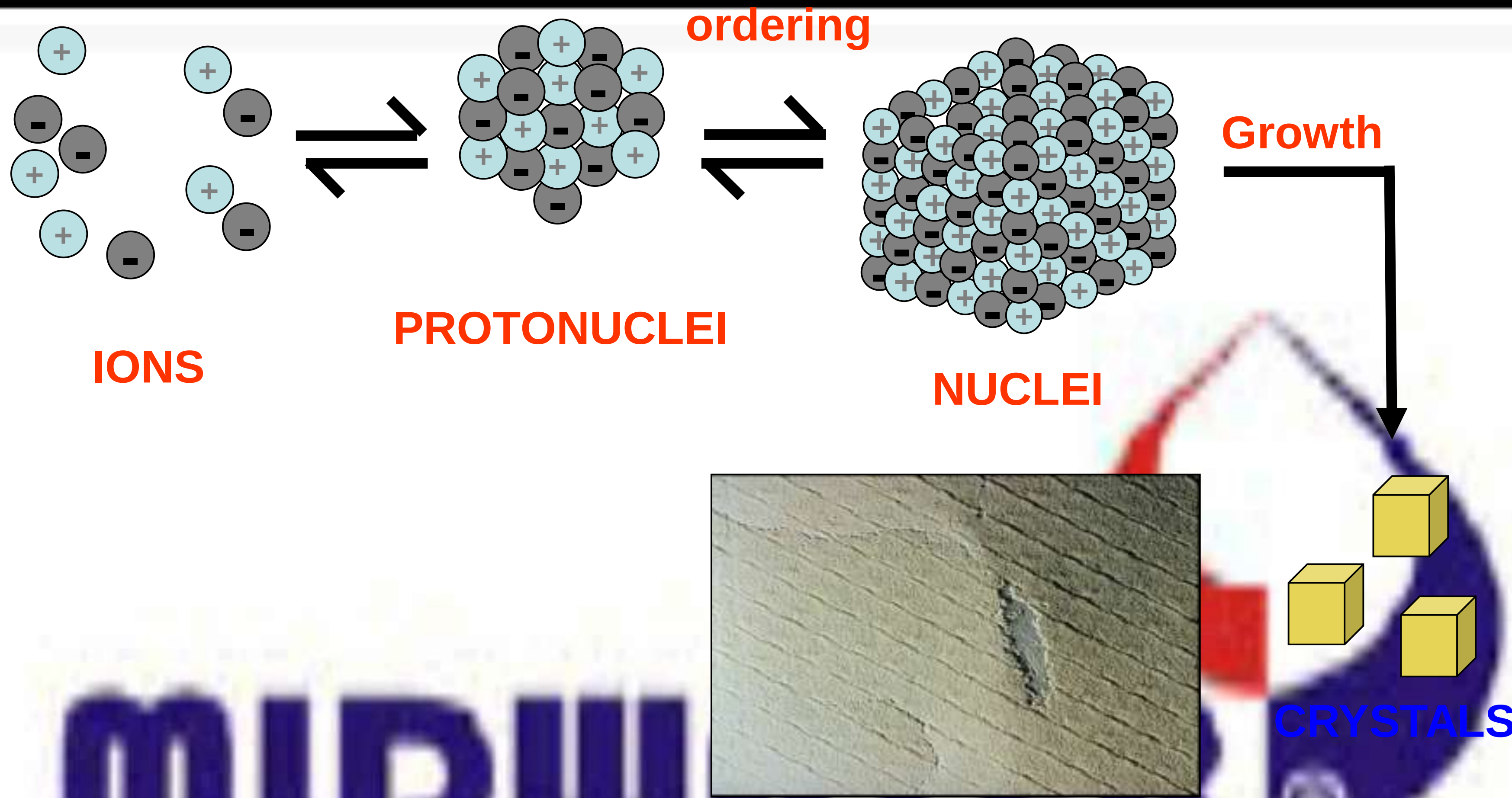
CHEMICAL FOULING SCALE FORMATION

SCALE FORMS IN THREE STAGES



Picture of scaled membrane

CHEMICAL FOULING SCALE FORMATION

Solution….

- **Identify Scale.**
- **Check Water Analysis.**
- **Calculate Saturation Limits (HYDREX^{TM} Antiscalant Dosing Calculator ASDC).**
- **Use Effective Antiscalant – HYDREX^{TM}**
- **Reduce Recovery (if necessary).**

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METHODS OF CONTROLING SCALE FORMATION

MECHANISM TO CONTROL SCALE DEPOSITION

TYPES OF ANTISALANT

1. THRESHOLD EFFECT

These inhibitors, when used is <u>sub-stoichiometric</u> amount is capable of retard the precipitation of salts from a supersaturated solution. **e.g., Phosphonate-based products.**

2. CRYSTAL GROWTH INHIBITION / CRYSRAL DISTORTION.

These inhibitors distort normal crystal growth and produce an irregular crystal structure with poor scale forming ability.

e.g., polyacrylic acid $[CH_2CHCOOH]_n$ with molecular weights in the 1,500–2,500 range.

3. DISPERSANCY :

Dispersants work by placing a surface charge on the crystal. Comparable charges cause the crystals to repel one other and are dispersed into the water bulk.

METHODS OF CONTROLING SCALE FORMATION

Common active substances used for scale control :

H^+	: Acid (used as H_2SO_4 or HCl).
$O\text{-}P(O)_2 – O$	: Polyphosphate.
$O_3P\text{-}C$	: Phosphonate.
$(CH_2\text{-}CH\text{-}COOH)_n$	: Polyacrylic acid.

HYDREX™ ANTISCALANT RANG OF PRODUCTS

PRODUCT

- HYDREX™ 4101
- HYDREX™ 4102
- HYDREX™ 4103
- HYDREX™ 4104
- HYDREX™ 4105
- HYDREX™ 4106
- HYDREX™ 4107

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Trouble-Shooting Guidelines

Possible Fouling	Possible Location	Pressure Drop	Feed Pressure	Salt Passage
Metal Oxide Fouling **(e.g.Fe,Mn,Cu,Ni,Zn**	**1st stage lead elements**	**Rapid increase**	**Rapid increase**	**Rapid increase**
Colloidal Fouling (organic and/or inorganic complexes)	**1st stage lead elements**	**Gradual Increase**	**Gradual Increase**	**Slight Increase**
Mineral Scaling (e.g. Ca, Mg, Ba, Sr)	**Last stage tail elements**	**Moderate Increase**	**Slight increase**	**Marked Increase**
Polymerized Silica	**Last stage tail elements**	**Normal to increased**	**Increased**	**Normal to increased**
Biological Fouling	**Any stage, usually lead Elements**	**Marked Increase**	**Marked Increase**	**Normal to Increased**
Organic Fouling **(dissolved NOM)**	**All stages**	**Gradual increase**	**Increased**	**Decreased**

Cleaning Process Conditions

Cleaning and Flushing Flow Rates per RO Pressure Tube (Pressures are not to exceed 60 psi (4 bar) at inlet to tubes.)		
Element Diameter	**GPM**	**LPM**
4-inches	6 to 10	23 to 38
6-inches	12 to 20	46 to 76
8-inches	24 to 40	91 to 151
8.5-inches	27 to 45	102 to 170

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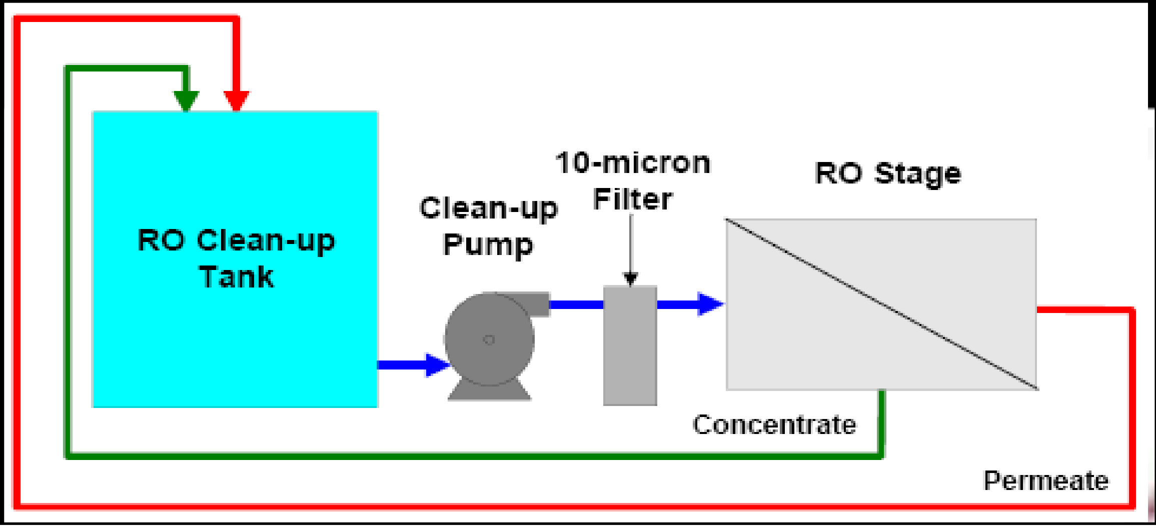
Cleaning Process

R.O CLEAN UP SKID



Cleaning Solution Volume Requirement per RO Element
(these volumes do not include volumes required for piping, filters, etc)
(these volumes do not include initial 20% of volume dumped to drain)

Element Size	Normal Fouling (Gallons)	Heavy Fouling (Gallons)	Normal Fouling (Liters)	Heavy Fouling (Liters)
4 x 40 inches	2.5	5	9.5	19
6 x 40 inches	5	10	19	38
8 x 40 inches	9	18	34	68