
Technical Presentation

RO Basics

MWQA

October 2017

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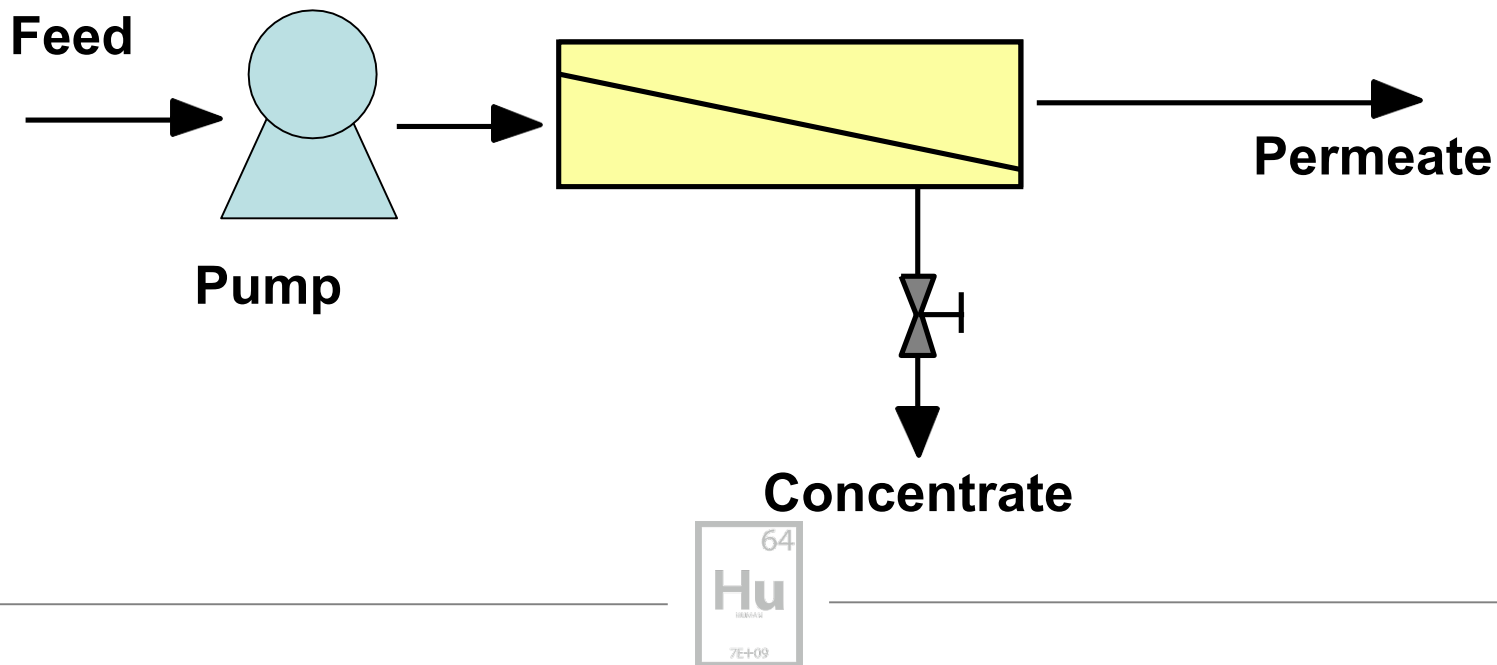
Technical Services & Development

Dow Water & Process Solutions



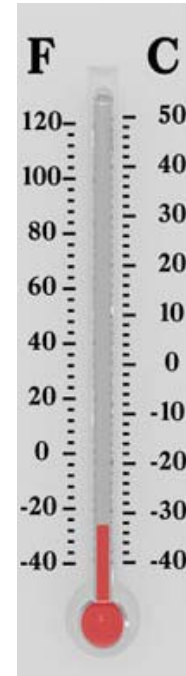
Factors that Impact RO Performance

- Temperature
- Pressure
- Salt Concentration



Temperature Effects

- RO permeate flow is strongly dependent on the temperature of the feed water
- The higher the temperature the higher the permeate flow
- Why? Lower viscosity makes it easier for the water to permeate through the membrane barrier
- **RULE OF THUMB** - for every 1°C the permeate flow will increase ~ 3%



Temperature Variations on Water Flux

Temperature	Correction	Temperature	Correction	Temperature	Correction	Temperature	Correction
C	Factor	C	Factor	C	Factor	C	Factor
12.0	1.588	16.0	1.371	20.0	1.189	24.0	1.035
12.1	1.582	16.1	1.366	20.1	1.185	24.1	1.031
12.2	1.576	16.2	1.361	20.2	1.180	24.2	1.028
12.3	1.570	16.3	1.356	20.3	1.176	24.3	1.024
12.4	1.564	16.4	1.351	20.4	1.172	24.4	1.021
12.5	1.558	16.5	1.347	20.5	1.168	24.5	1.017
12.6	1.553	16.6	1.342	20.6	1.164	24.6	1.014
12.7	1.547	16.7	1.337	20.7	1.160	24.7	1.010
12.8	1.541	16.8	1.332	20.8	1.156	24.8	1.007
12.9	1.536	16.9	1.327	20.9	1.152	24.9	1.003
13.0	1.530	17.0	1.323	21.0	1.148	25.0	1.000

- Membrane manufacturers provide temperature correction tables for more accurate conversions.



TCF Factors

Temperature		Temperature		Temperature		Temperature	
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- Example: if a membrane produced 100 gpd at 21°C how much would it produce at 25°C?
- $100 \text{ gpd} * 1.148 = 114.8 \text{ gpd}$
- A 14.8% increase
- $4 * 3\% = 12\%$



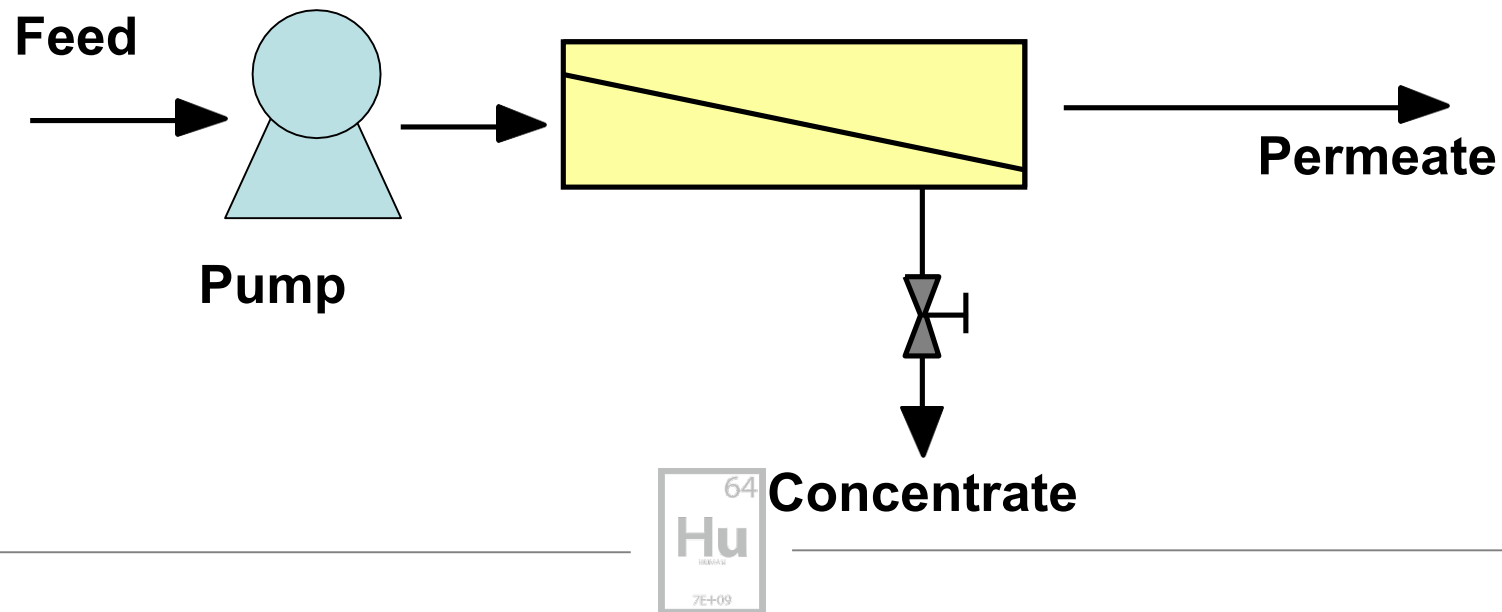
Temperature Variations on Salt Passage

- Rule of Thumb: salt passage increases 6% for 1°C increase.
- Increasing temperature increases salt passage more than water passage.
- Generally you will get better rejections at lower temperatures.



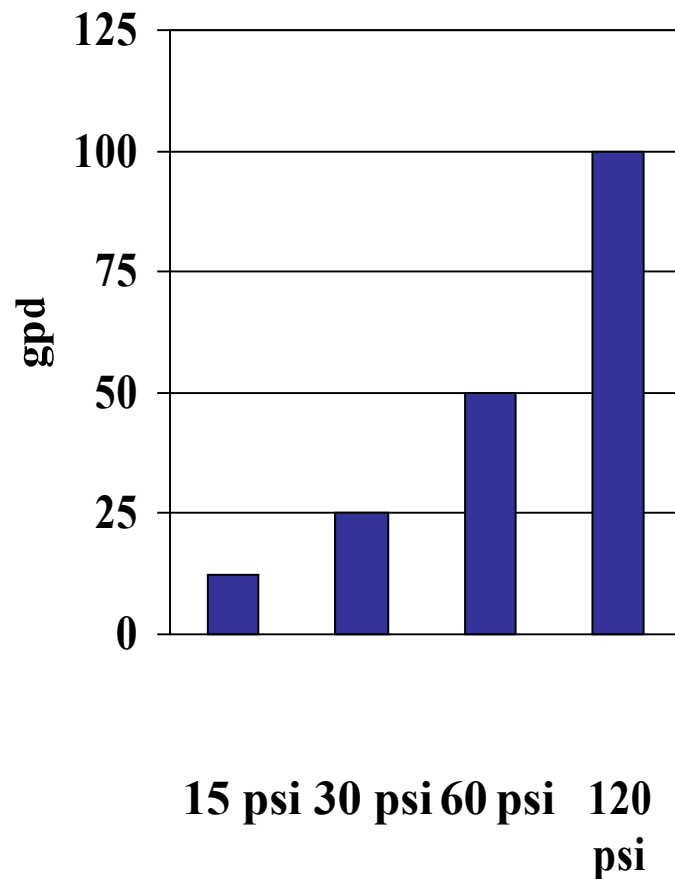
Factors that Impact on RO Performance

- Temperature
- Pressure**
- Salt Concentration



Pressure Effects

PSI



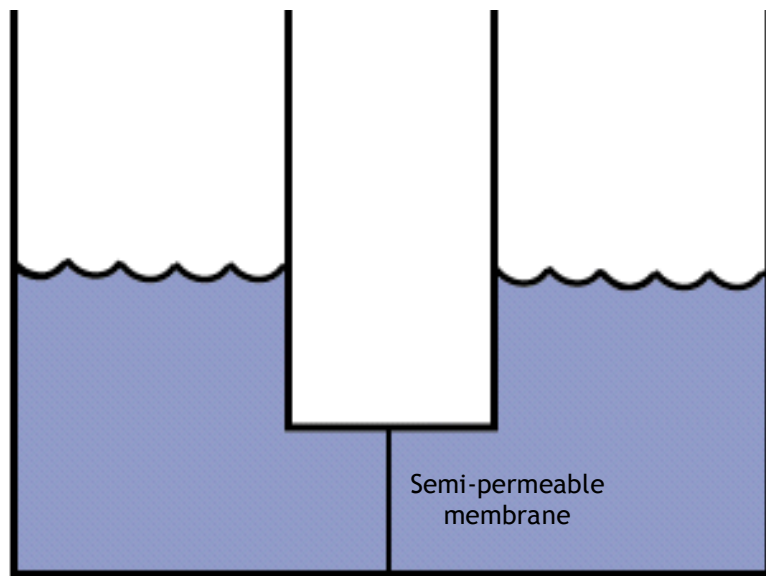
- If you double net driving pressure (NDP) to an RO unit you will double your permeate flow.
 - NDP is the sum of all forces acting on the membrane
-

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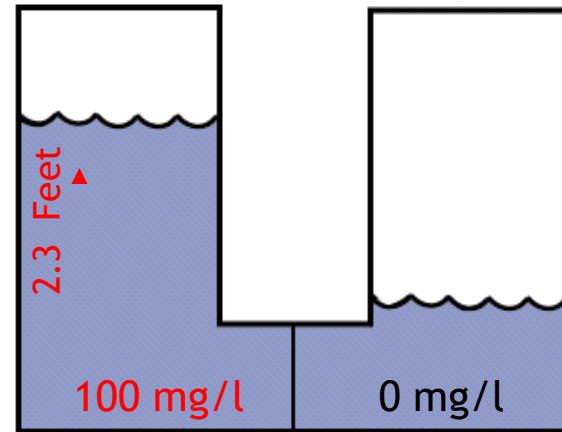
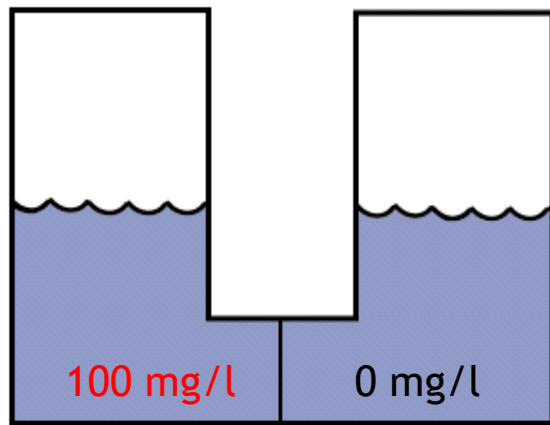
What is Osmosis?



- Movement of water through a semi-permeable membrane from an area of lower concentration to an area of higher concentration



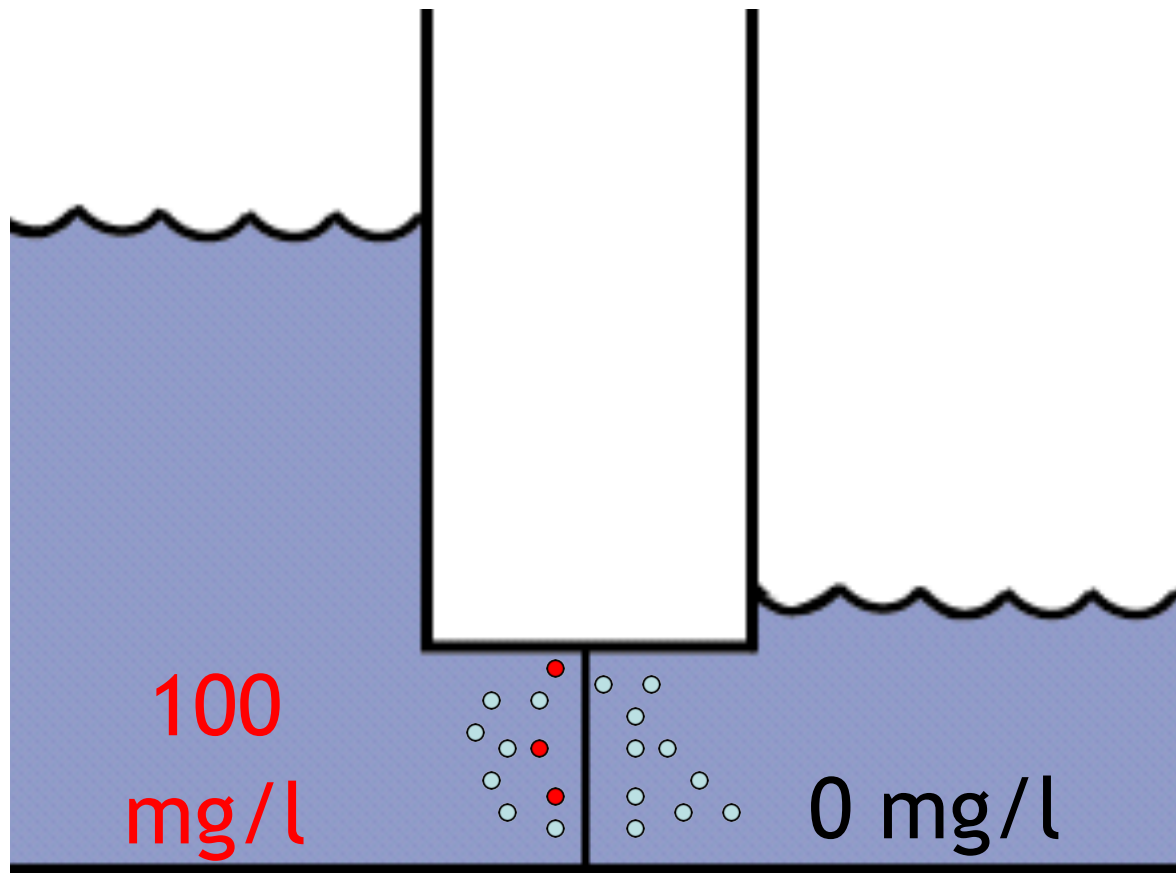
What is Osmotic Pressure?



- If we add salt to one side of the vessel the water level will rise.
- How far will the water level rise?
- **RULE OF THUMB** is 1 psi of pressure for every 100 ppm TDS (1 psi equals 2.3 feet of water head).

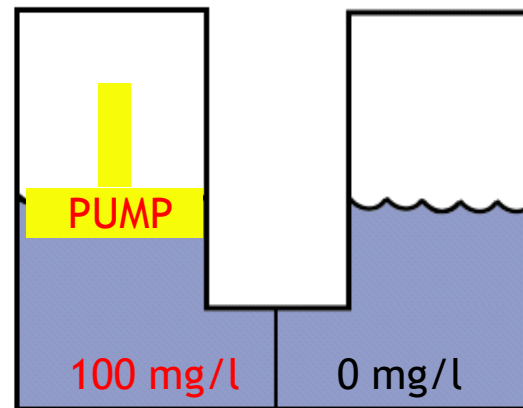
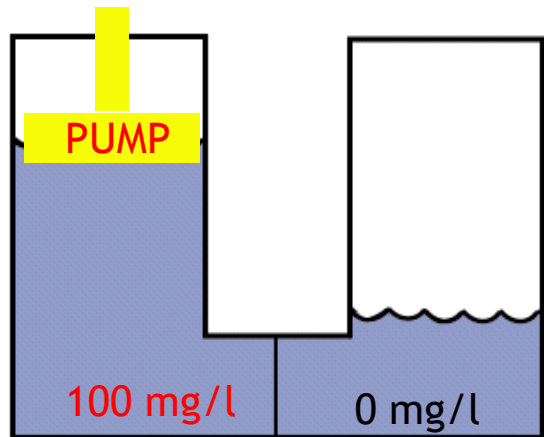


Why does Osmosis Occur?



There are a greater number of water molecules colliding with the membrane on the pure water side.

What is Reverse Osmosis?



- Osmotic Pressure must be overcome
 - In this case how much pressure would have to be applied to overcome the osmotic pressure?
 - Answer: 1 psi
-



What is Net Driving Pressure?

- Sum of all forces acting on the membrane
- Pump or Feed pressure
- Back pressure from line restrictions and downstream filters.
- Osmotic Pressure of the feed and permeate water



NDP Examples

50 psi

150 psi

Pump

Pump

100 mg/l

0 mg/l

1000 mg/l

0 mg/l

Osmotic 0

Osmotic 0 psi

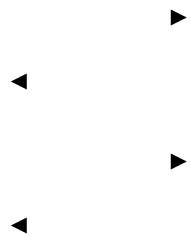
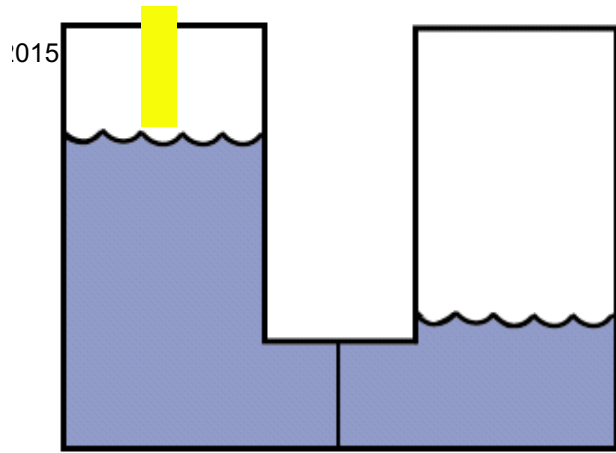
Pressure 1 psi

Pressure 10 psi

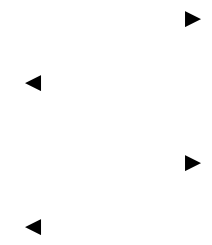
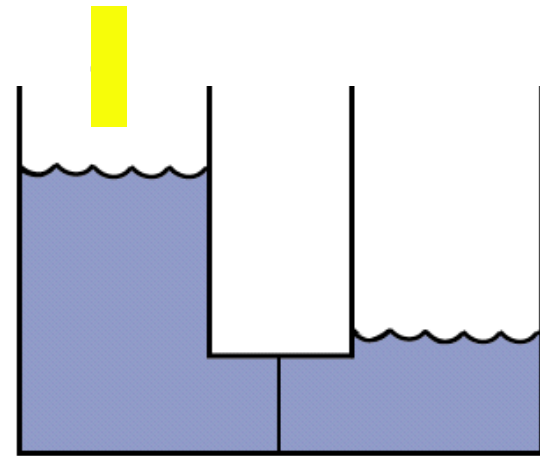
Applied Pressure 50 psi
0

Applied Pressure 150 psi
0

NDP = 49 psi

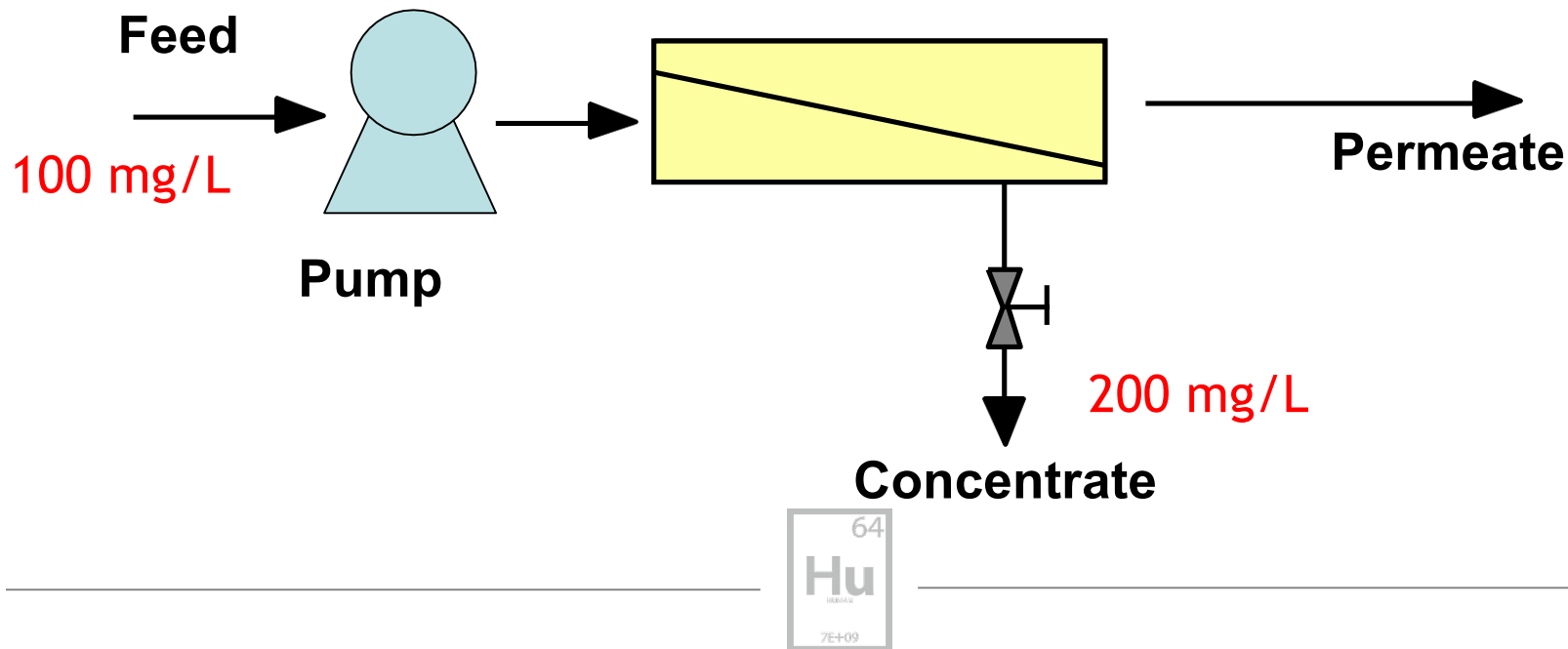


NDP = 140 psi



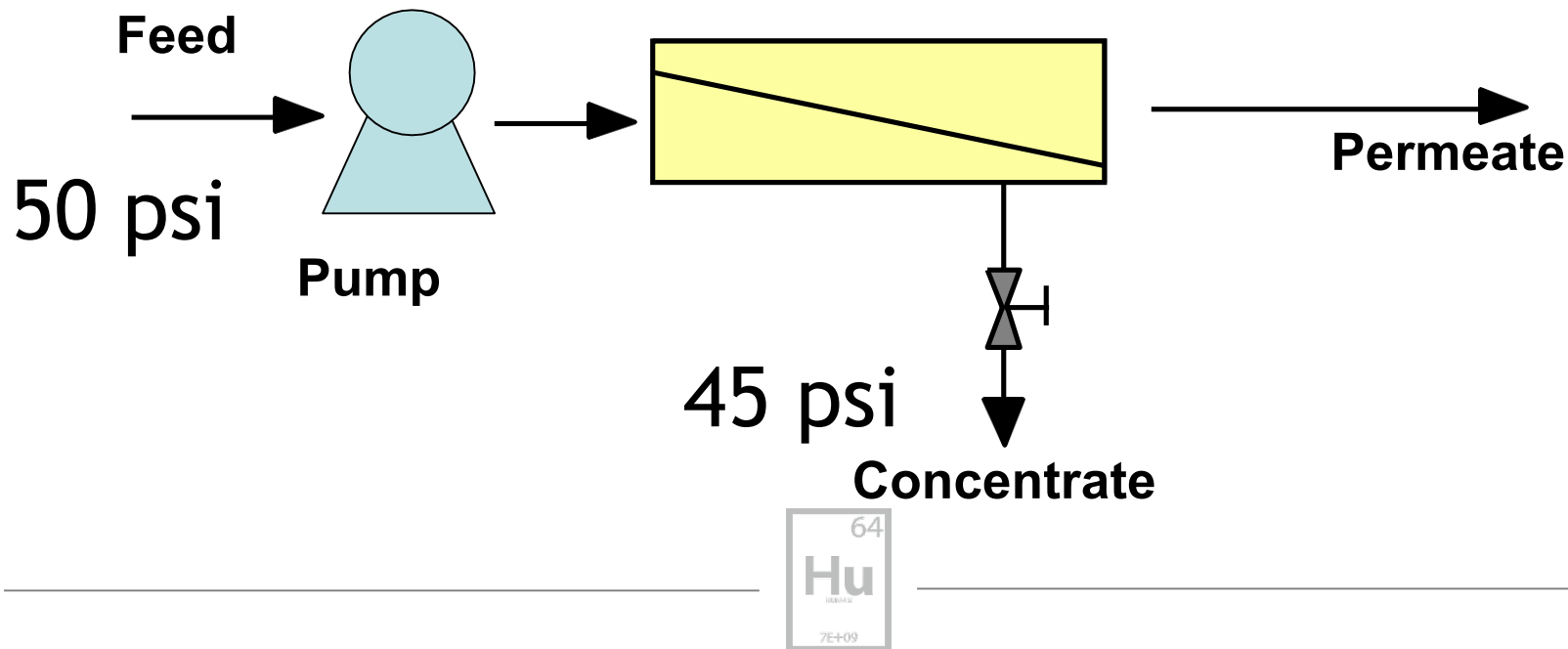
What is Average NDP?

Salt concentration is increasing continually as it passes over the membrane.



What is Average NDP?

Feed pressure is decreasing continually as it passes over the membrane



Average NDP

NDP Inlet: 50 psi - 1 psi = 49 psi

NDP Outlet: 45 psi - 2 psi = 43 psi

50 psi & 100 mg/l

Feed

Permeate

Pump

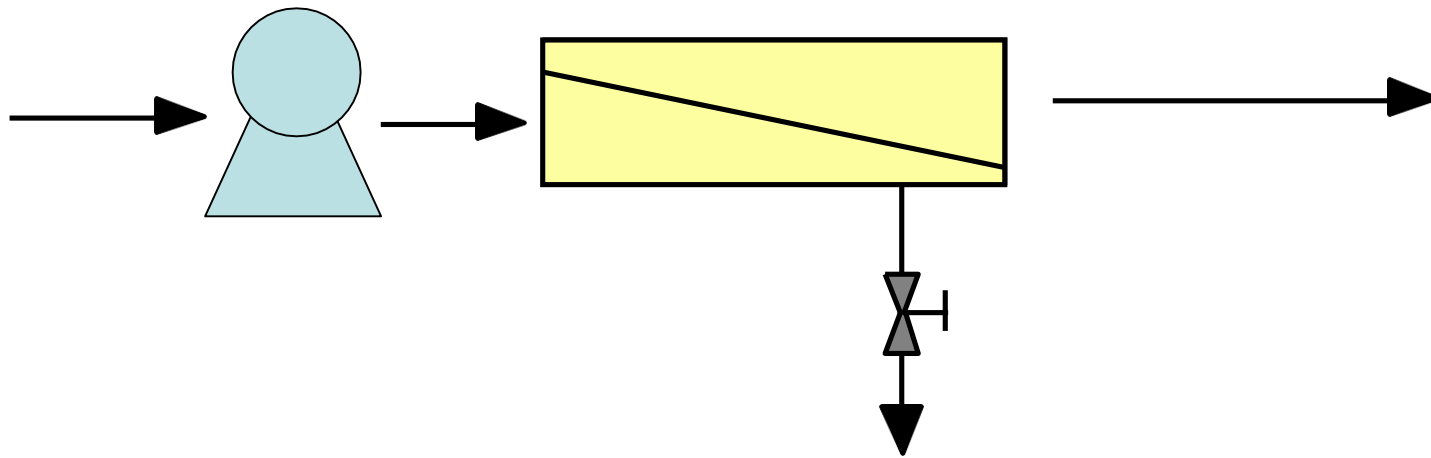
$$\text{NDP} = \frac{49 \text{ psi} + 43 \text{ psi}}{2}$$

45 psi & 200 mg/l

Concentrate

NDP = 46 psi





How does pressure affect the rate of salt passage?

- The rate of salt passage through a membrane is independent of pressure.



Rate of Salt Passage is *Independent* of Pressure

NDP 100 psi
Salt Concentration
100 mg/l



Membrane



Salt Concentration
5 mg /l liter

Salt Passage = 5 mg/l

NDP 200 psi
Salt Concentration
100 mg/l



Membrane



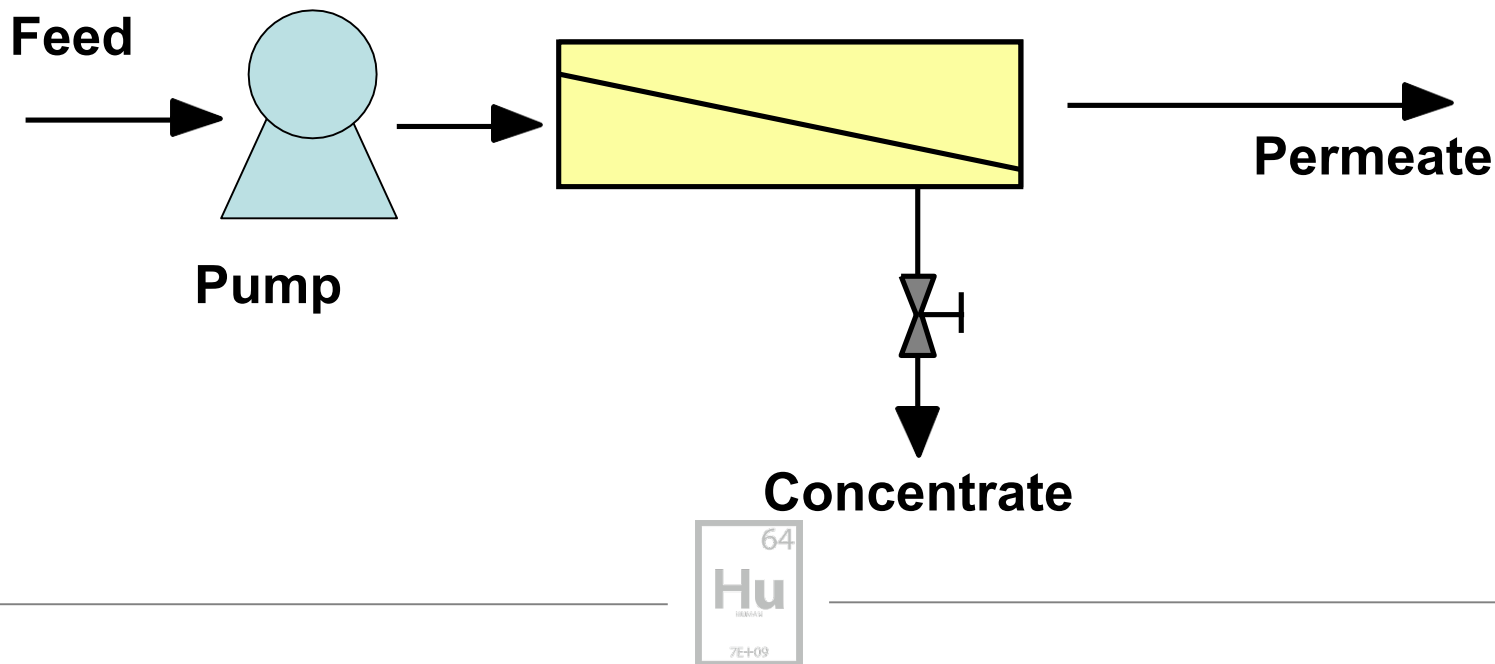
Salt Concentration
5 mg/2 liters

Salt Passage = 2.5 mg/l

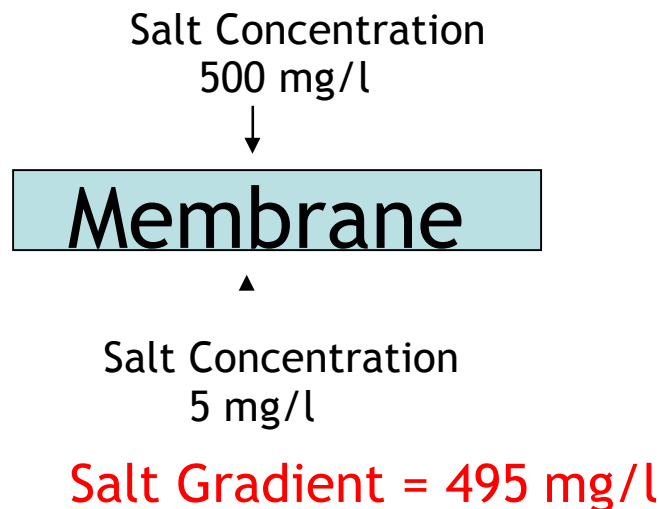


Factors that Impact on RO Performance

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Effect of Salt Concentration



- Rate of salt passage is determined by the salt concentration gradient.
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Effect of Salt Concentration

(continued)

- What effect would higher salt concentration have on permeate flow?
- Higher salt concentration will decrease the permeate flow.
- Why? Because higher osmotic pressure will reduce the NDP.
- What effect would higher salt concentration have on the rate of salt passage?
- Higher salt concentration will increase the salt concentration gradient and increase the rate of salt passage.
- Overall water quality is lower for two reasons, higher rate of salt passage combined with less permeate water.



Review Questions

- As water temperature increases what will happen to permeate flow?
- It will increase due to a decrease in water viscosity.
- What will happen to salt passage?
- It will also increase but at a greater rate than the increase in permeate flow.
- What will happen to overall permeate quality?
- It will go down because the increase in salt passage is greater than the increase in permeate flow.



Review Questions

- As NDP increases what will happen to permeate flow?
- It will increase, double the NDP and you double the permeate flow (other conditions being equal).
- What will happen to the rate of salt passage?
- *Rate of salt passage is independent of NDP and will not change.*
- What will happen to overall permeate quality?
- It will increase due to greater dilution of the same amount of salt.



Review Questions

- As salt concentration/salt gradient increases what will happen to permeate flow?
- It will decrease due to an increase in osmotic pressure.
- What will happen to the rate of salt passage?
- It will increase due to a higher salt concentration gradient.
- What will happen to overall permeate quality?
- It will go down due to a combination of lower permeate flow and higher salt passage.

