Membrane Filtration
Reverse Osmosis and Nanofiltration

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Outline

• Membrane introduction and definitions
• Use of RO and NF in metal finishing industry
• Example of hybrid system
• Clarkson research group
Membrane Types

• Pressure driven membrane processes
  – Low-pressure membranes
    • Microfiltration (MF) and ultrafiltration (UF)
  – High-pressure membranes
    • Reverse osmosis (RO) and nanofiltration (NF)

• Current driven membrane processes
  – Electrodialysis (ED) and electrodialysis reversal (EDR)
Pressure Driven Membranes

Low-pressure Membranes

High-pressure Membranes

Micro
MF

Ultra
UF

Nano
NF

RO

Suspended Solids (Particles)
Macromolecules (Humics)

Multivalent Ions (Hardness)

Monovalent Ions (Na⁺, Cl⁻)

Water Molecules

Low Molecular Weight Organics

Amy Childress, University of Nevada - Reno
RO/NF - A Few Definitions

- **Separation process**: components removed by membrane end up in another process stream

- **Flow rate of permeate produced per flow rate of feed water** termed **recovery**:

  \[
  \text{Recovery} = \left( \frac{Q_p}{Q_F} \right)
  \]

- **Efficiency of separation** called **rejection**:

  \[
  \text{Rejection} = \left( 1 - \frac{C_p}{C_f} \right)
  \]
Reverse Osmosis (RO)

- Dense polymeric membrane material
- Almost always configured into spiral-wound cross-flow elements
- Can achieve > 99% rejection of almost all solutes
- Relatively high pressure requirements (200 – 1000 psi)
- Recovery limited by pressure requirements and membrane fouling (usually < 80%)
Nanofiltration (NF)

- Prepared from variety of materials
  - Becoming more robust towards aggressive water matrices and solvents
- Selective rejection of divalent ions compared to monovalent ions
  - Under certain conditions can get negative rejection of monovalent ions – ions concentrated in permeate
  - Can be used to selectively separate components of feed stream by solute size and valence
- Lower pressure requirements than RO (50 – 200 psi)
- Potential to operate at higher recovery compared to RO
Comparing RO to NF

More Energy
Less Energy

Temp corr. specific flux (L·m⁻²·kPa⁻¹·hr⁻¹)

RO
NF

Sulfate (SO₄²⁻)
Nitrate (NO₃⁻)
Fluoride (F⁻)
Chloride (Cl⁻)
Magnesium (Mg²⁺)
Calcium (Ca²⁺)
Potassium (K⁺)
Sodium (Na⁺)
UV-254
Organic carbon
Conductivity

Rejection [-]

0 0.2 0.4 0.6 0.8 1
Application of RO in Metal Finishing Industry

• RO has been proposed or applied in the metal finishing industry to:
  – Produce high-quality rinse water
  – Reuse rinse water (removal of metals)
  – Reuse rinse water and recover metal complexes (Me-cyanide) for reuse in plating baths

• Issues to be aware of:
  – Cannot tolerate solids – need pretreatment (MF or UF)
  – Must treat/dispose of concentrate stream if not for reuse
  – RO membranes have narrow range of pH tolerance (3 – 9 for long-term operation)
  – Requires augmenting permeate stream with another source of water (amount depends on membrane recovery)
Application of NF in Metal Finishing Industry

- NF has been proposed or applied in the metal finishing industry to:
  - Produce high-quality rinse water (less effective than RO)
  - Separate metals from acids (acids freely permeate NF) for reuse of spent acid solutions
  - Separate metals from impurities (e.g., salts, anions, undesirable metal complexes)

- Issues to be aware of:
  - Cannot tolerate solids – need pretreatment (MF or UF)
  - Selective separations are difficult to optimize
  - Acidic conditions can destroy certain membranes
  - Solutions may require pre-concentration to achieve goals
Hybrid System

- Acidic liquor treatment and reuse ($\text{Cu}^{2+}/\text{H}_2\text{SO}_4$)
- Incorporates RO and NF to recover water, sulfuric acid and, potentially, copper
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• My main research focus has been on municipal wastewater reuse using membrane technology:

  - WWTP
  - MF/UF
  - NF/RO
  - AOP
  - DW

• Any membrane application requires optimization:
  - Reducing energy consumption while meeting effluent water quality goals
  - Preventing membrane fouling and deterioration
  - Maximizing system recovery
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• Past and Current Research:
  – Modeling and optimizing membrane separations
  – Evaluating membrane fouling and filterability
  – Testing novel membrane systems

• Capabilities
  – Bench- and laboratory-scale membrane testing systems
  – Wide range of analytical capabilities
    • Metal analysis (ICP, AAS)
    • Organic analysis (GC-ECD, GC-FID, GC-MS/MS, etc.)
    • Surface analysis (SEM microscopy, XRD analysis)
Thank You

Feel free to contact me:

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