MEMBRANE SEPARATION(RO, MICRO/ULTRA FILTRATION)

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CM3120

02/19/2021

PRESENTATION OUTLINE

- Description of membrane separation
- Basic mass and energy balance equations
- Basic design and operating principles
- Uses of membrane separation
- Limitations of membrane separation
- Applications of membrane separation in industries
- Differences with other unit operations

PROCESS DESCRIPTION

- Membrane separation is a technology which selectively separates materials via pores and/or minute gaps in the molecular arrangement of a continuous structure. Membrane separations are classified by pore size and by the separation driving force.
- A membrane is a selective barrier that allows the passage of certain components and retains others in the liquid or gas mixture
- The stream that enters the membrane is called feed-stream, the fluid that passes through the membrane is known as the permeate while the fluid that contains the retained components is named retentate or concentrate.

PROCESS DESCRIPTION (CONT'D)

- Flux is the rate of extraction of the permeate expressed as meters per membrane area per time unit
- Fouling occurs when solids deposited in the membrane impedes flow through the membrane
- Reverse osmosis (RO), ultrafilters (UF), and microfilters (MF) are membrane e technologies that employ pressure across the membrane as the driving force for separation.

WHEN IS IT USED?

- When dissolved salts must be removed
- Biological materials which are very sensitive to their physical and chemical environment.
- When aseptic operation is required

MEMBRANE SEPARATION BY PRESSURE

- Reverse osmosis
- Ultra filtration
- Micro filtration
- They differ based on the membrane pore size used and amount of pressure applied

WHY USE MEMBRANE SEPARATION?

- It saves energy costs (ambient temperature operation)
- Often easier to operate compared to other alternatives
- Lower capital cost

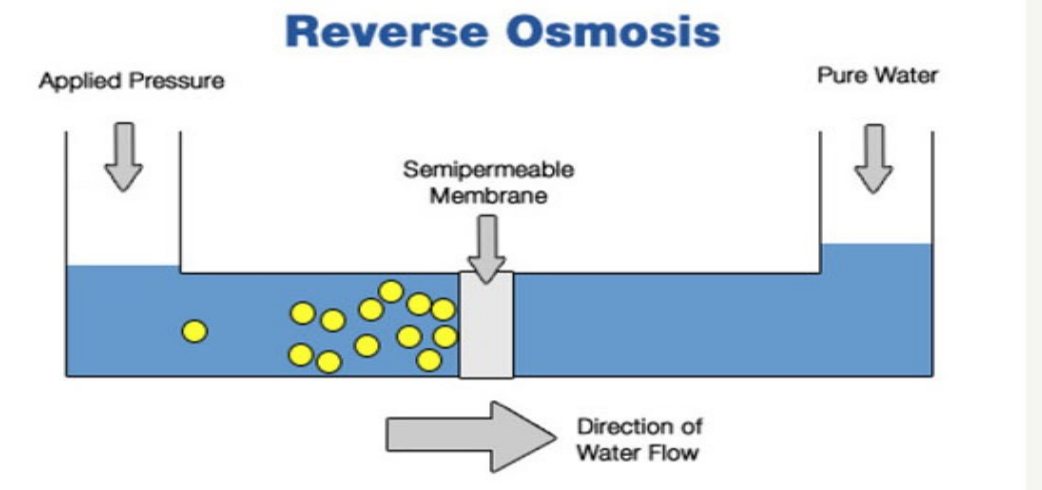
REVERSE OSMOSIS

- Reverse osmosis (RO) is a water purification process that uses a partially permeable membrane to separate ions, unwanted molecules and larger particles from drinking water.
- Water flows from the more concentrated side (more contaminants) of the membrane to the less concentrated side (fewer contaminants) to provide clean drinking water.
- Removes dissolved solids and salt or water
- Pore size of membrane varies from 10^-4µm to10^-3µm with pressure of 30-60 bar

OSMOTIC PRESSURE

- Osmotic pressure is the pressure that must be applied to a solution in order to prevent pure solvent from going through the semi-permeable membrane separating the two liquids
- It is the pressure required to counter, not sustain, osmosis.

REVERSE OSMOSIS



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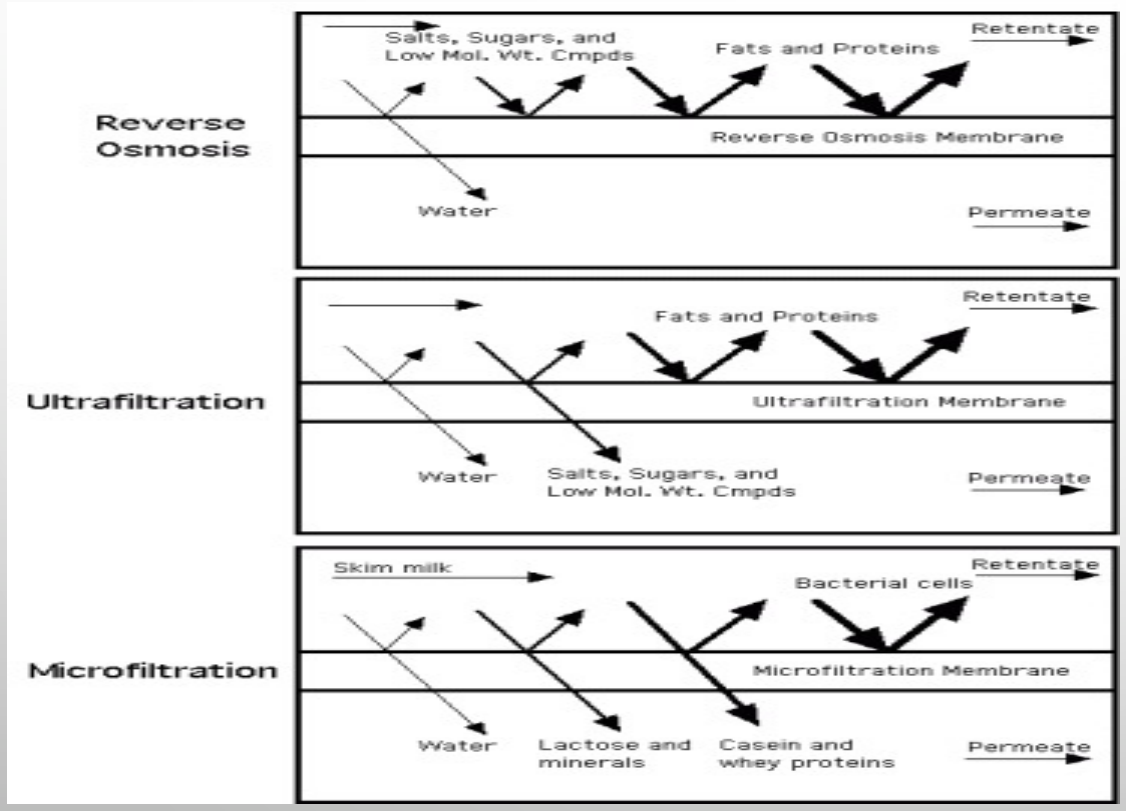
ULTRA-FILTRATION

- Ultrafiltration will filter out the vast majority of contaminants like sediment, chlorine, and cysts.
- For people who want to retain minerals like calcium and magnesium in their water, ultrafiltration has the advantage.
- Ultrafiltration is not going to eliminate dissolved solids or salts
- 10^-2µm to 10^-1µm membrane pore size with pressure between 1-10 bar used

MICROFILTRATION

- Microfiltration is a type of filtration physical process where a contaminated fluid is passed through a membrane to separate microorganisms and suspended particles from process liquid
- Mostly used to remove biological organisms from liquid mixtures
- Usually serves as pre-treatment stage for UF and RO
- 0.1µm to 10µm membrane size with less than 1 bar used
- Can be used prior to RO to reduce fouling

RO, UF & MF



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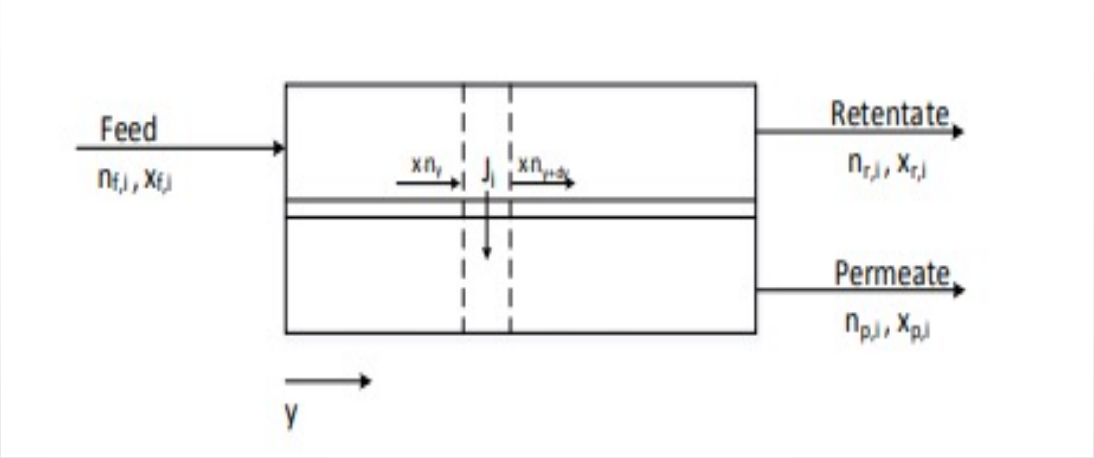
MASS BALANCE



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BASIC MASS BALANCE

$$\dot{n}_f = \dot{n}_p + \dot{n}_r = \sum_i \dot{n}_f x_{i,f} = \sum_i \dot{n}_p x_{i,p} + \sum_i \dot{n}_r x_{i,r} \qquad (1.1)$$

- Overall mass balance (hyp.: No chemical reactions)
- Where $\dot{n}_f$ is the total molar flow-rate in the feed stream;
- $\dot{n}_p$ is the total molar flow-rate in the permeate stream;
- $\dot{n}_r$ is the total molar flow-rate in the retentate stream;
- x_i is the molar fraction of component i.

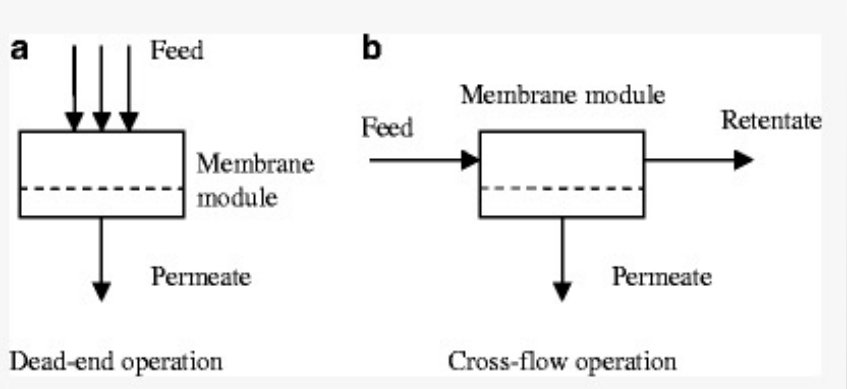
BASIC DESIGN AND OPERATING PRINCIPLES

- Factors to be considered are:
- Membrane material
- Module type- Tubular, plate and flame, spiral-wound, etc.
- Operating pressure
- Pre-treatment requirement
- Flux

TYPES OF OPERATIONS

Two types of operation

- Dead-end operation
- Cross-flow operation



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USES OF MEMBRANE SEPARATIONS

- Salt desalination
- Treatment of wastewater streams
- Production of ultra pure water
- Separation of food products
- Drug delivery
- Dialysis

MOST COMMON INDUSTRIAL APPLICATIONS OF MEMBRANE SEPARATION

- Food industry
- Water treatment
- Pharmaceuticals

LESS COMMON INDUSTRIAL APPLICATION OF MEMBRANE SEPARATION

- Carbon capture
- Removal of acid gases from natural gas streams
- Biogas production & processing

LIMITATIONS

- It is a slower process compared to similar separation processes
- Storage for wastewater takes a lot of space
- Uniformity of pore sizes
- Dealing with fouling and cleaning
- Membranes are mechanically not very robust and can easily be destroyed by a malfunction in the operating procedure
- Membrane processes sometimes require excessive pretreatment due to their sensitivity to fouling.

DIFFERENCES BETWEEN FILTRATION AND MEMBRANE SEPARATION

- Gravity is the driving force of filtration while pressure is the driving force of membrane separation
- Flow is perpendicular to the filter used for filtration while flow is along the surface of the membrane for membrane separation
- For filtration, the filter remains caked up as the retentate increases over time while for membrane separation, the caked layer remains continuously swept off by incoming liquid, keeping the membrane layer low
- There's a higher flux maintained over a long time for membrane separation as compared to filtration.
- Filtration takes place in an open system (exposed to the atmosphere) while membrane separation takes place in a closed system
- Membrane separation is used for particles that are less than 10µm while filtration is used for 10µm and above

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