# Osmotically-Driven Membrane Processes for Sustainable Water Reuse and Resource Recovery: Exploration of Branched Polyethyleneimine as Osmotic Agent

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# Membrane-Based Separation Processes

**# Separation science** plays a major role to maintain the global sustainability

**# Membrane-base separation processes**

**< Advantages >**

(i) Easy and simple operation

(ii) Low cost & energy requirements

(iii) Easily combined into hybrid systems with scalability

(iv) Environmental-friendly processes

# Osmotically-Driven Membrane Processes

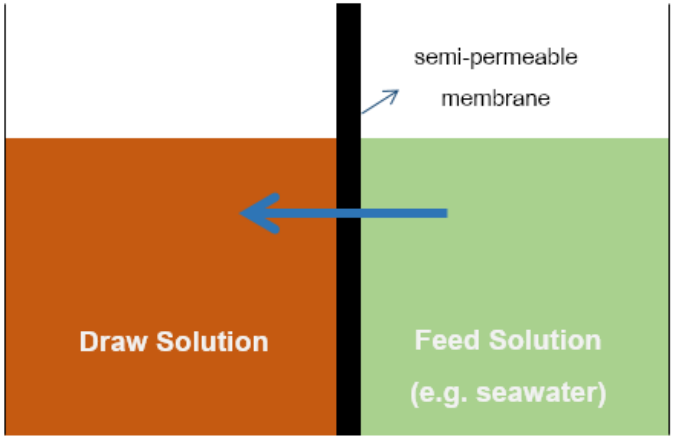
# Emerging membrane-based separation technology

# Driving force : **Osmotic gradients**

| Forward Osmosis (FO) | | Pressure Retarded Osmosis (PRO) |
|---|---|---|
|  |  |  |

# Principle of Forward Osmosis (FO)

$\mu_{w,draw} < \mu_{w,feed}$

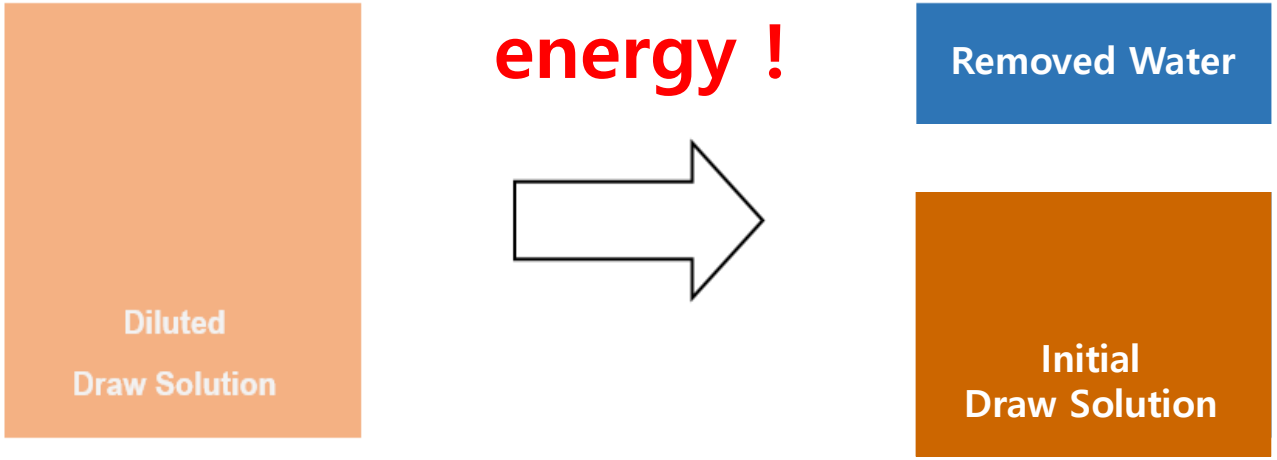



Initial Condition

**no energy !**

# Potential to be an **energy-efficient separation process** with **low membrane fouling**

# Principle of Forward Osmosis (FO)




# Draw solution regeneration step determines the **total energy consumption of FO**

# Therefore, selection of a **draw solute** & its **regeneration method** is crucial for the viability of FO

# Selection of Draw Solutes for FO

## REQUIREMENTS

**Cost-effective**

**Non-toxic/hazardous**

**High solubility**
(High osmotic pressure)

**Low viscosity**

**Easy regeneration**

**Osmotic pressure : Colligative property**

( Van't Hoff equation : $\pi = i * \frac{n_s}{V} RT$ )

→ **Inorganic salts, Small organic molecules**

| **Draw solute** | $MgCl_2$ | $NH_4HCO_3$ | Glucose |
|---|---|---|---|
| **Regeneration method** | NF, RO | Low Grade Heat ~60℃ | NF |

## Advantages

**High osmotic pressure**

## Disadvantages

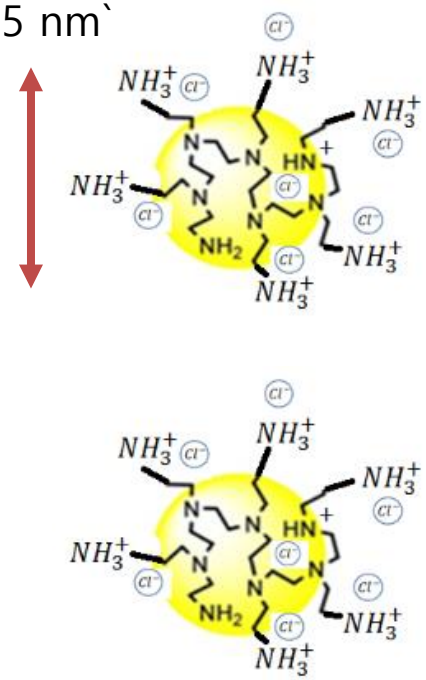
**Energy-intensive**

**High reverse solute diffusion**

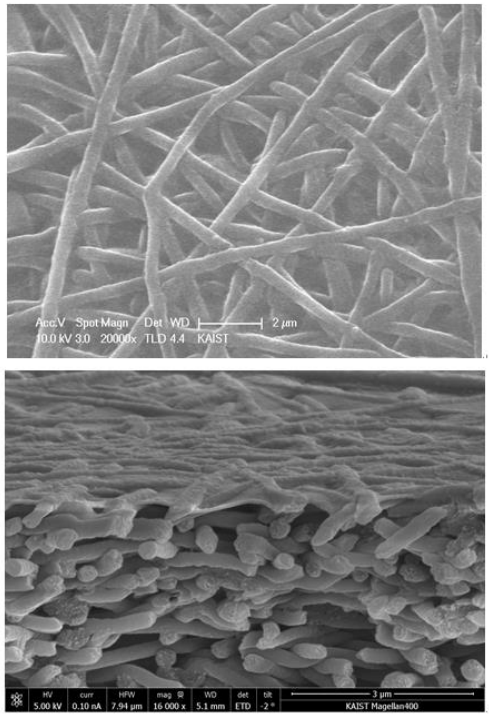
# New FO Process

**PEI Draw Solutions**

~ 5 nm`



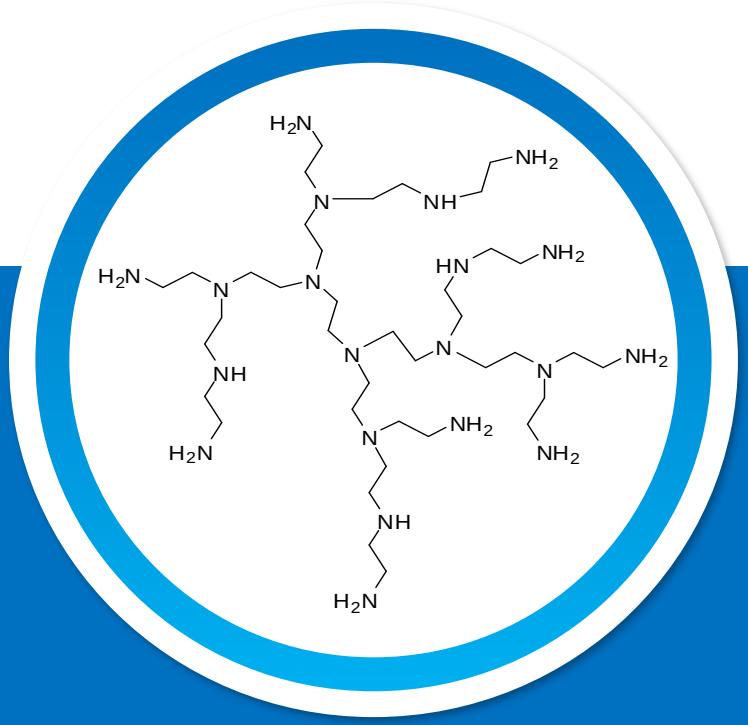
**Nanofibrous PAN FO membrane with a Porous NF selective layer**





Cho, M. et al. (2016). *Journal of Membrane Science*.

# Branched Polyethyleneimine (PEI) as Osmotic Agent




## Advantages

i. Cost-effective

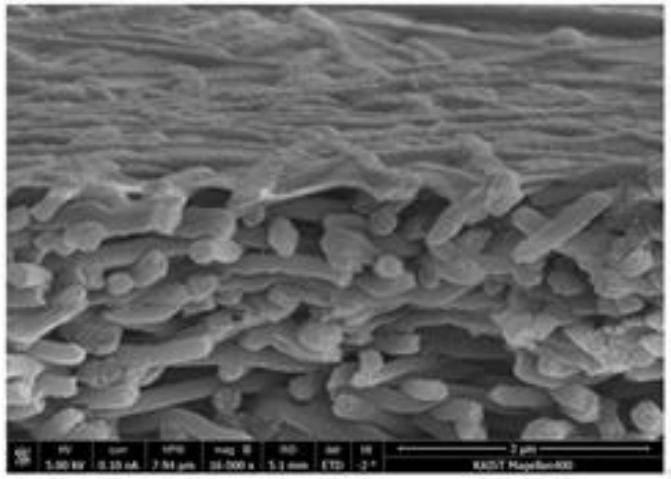
ii. Muti-functional

iii. Easily regenerated by low energy

# Nanofibrous Composite FO Membranes

**# Electrospinning** -> Highly porous nanofibrous support layer

**# Interfacial polymerization** -> Thin NF-like selective layer



Interfacial Polymerization

**A NFC FO membrane**

( A ~ 7 bar/LMH, S ~ 200um )



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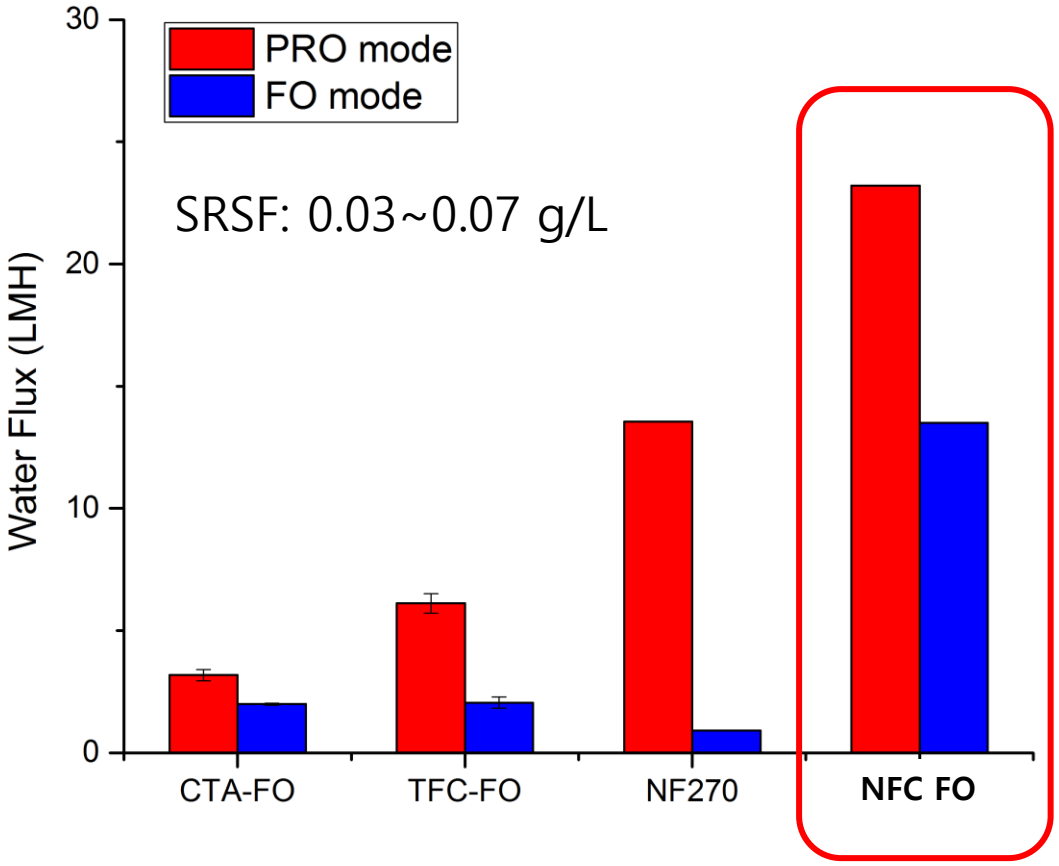
# Increased Permeate Fluxes with Low Reverse Solute Diffusion



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# Draw Solution Regeneration by Ultrafiltration

| PEI Concentration (wt%) | UF Permeate Flux (LMH) | PEI Rejection (%) |
|---|---|---|
| **5.0** | 14.3 | 94 |
| **2.5** | 38.8 | 98 |

- Effective UF regeneration of PEI



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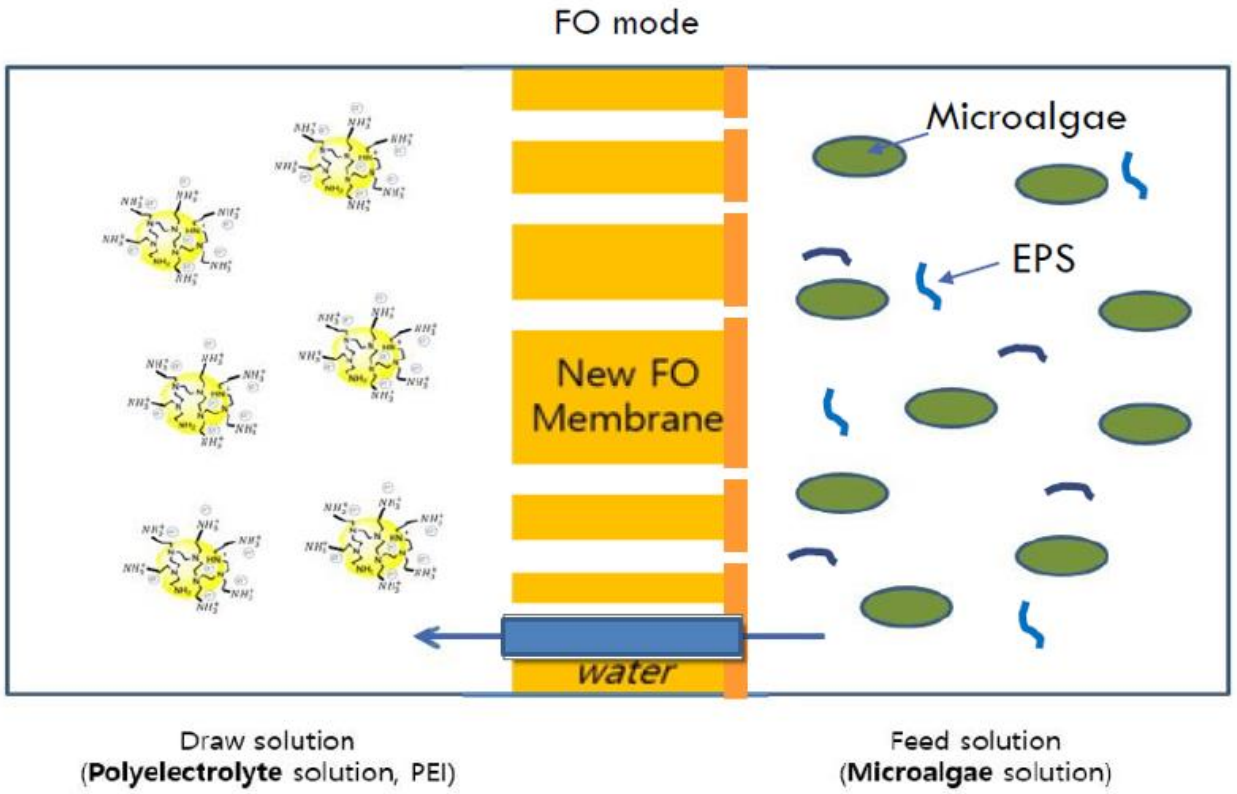
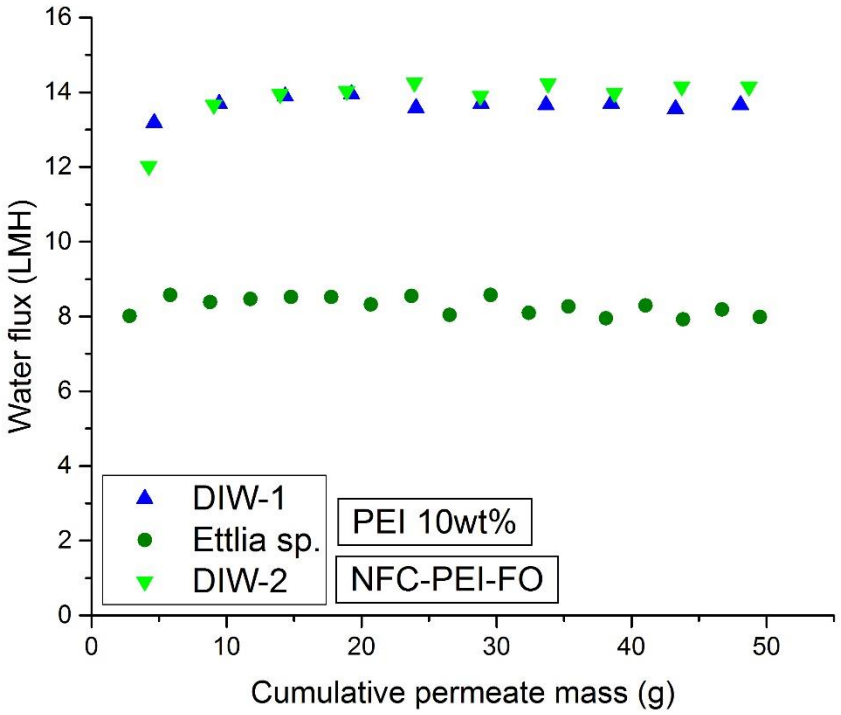
# Applications: Separation of Microalgal-based Colloidal Suspensions



# FO Separation of Microalgal Suspensions




**No irreversible fouling**
**(Flux recovery rate : ~ 100 %)**



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# Conclusions

- Utilization of macromolecular PEI draw solutes and nanofibrous FO membranes with a porous NF-like separation layer has shown a potential in terms of high permeate flux and low reverse solute diffusion

- Utilization of the PEI FO process for the separation of microalgal-based colloidal suspensions was effective (Flux recovery rate: ~ 100 %)

- The PEI FO process can be applied to water reuse & resource recovery