Advanced Treatment by Membrane Processes

presented by

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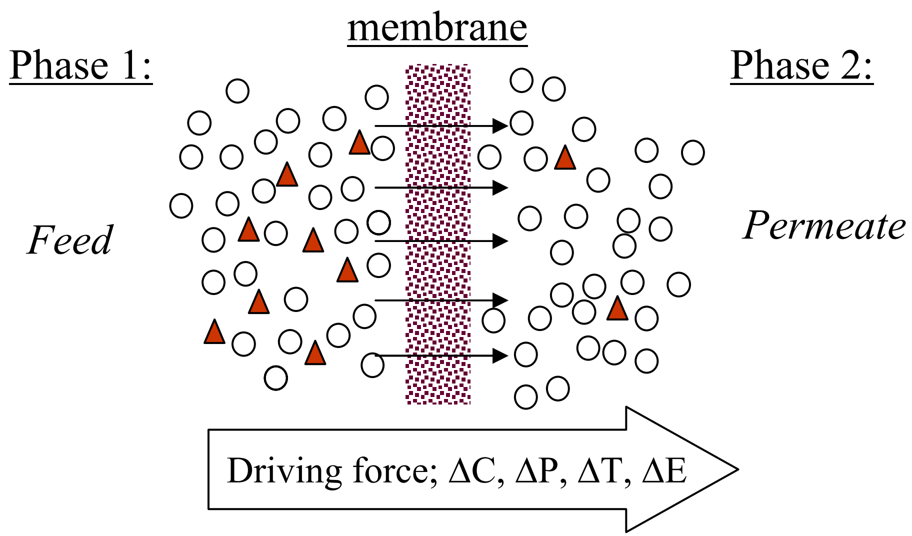
Fundamentals of membrane technology

Definition:

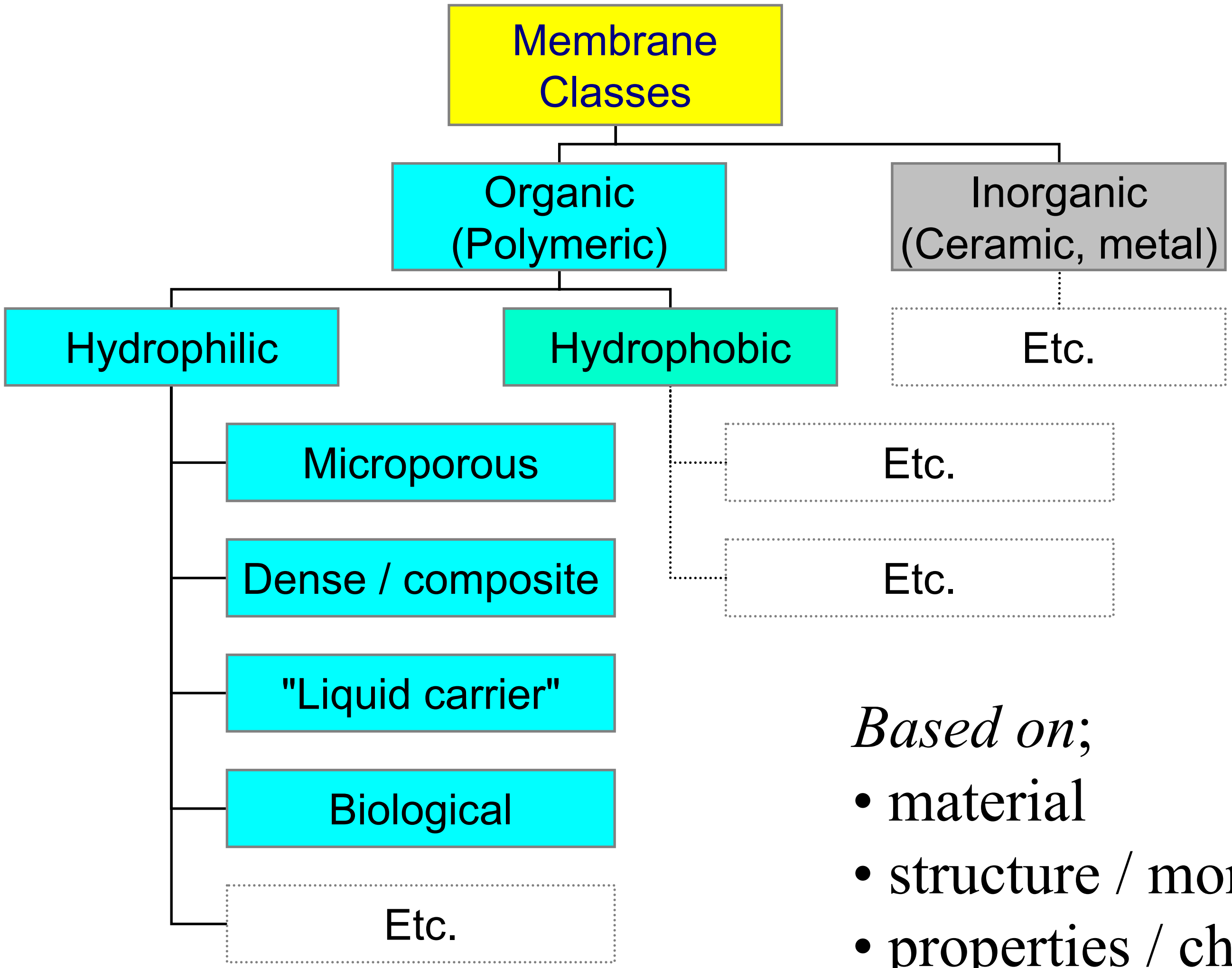
A membrane is a permselective barrier, or interface between two phases, and the separation process takes place due to a specific driving force transporting a compound through the membrane from the one phase to the other



Mass transport:

1. Through phase 1
2. Across the membrane
3. Through phase 2

Classifying membranes:



Based on;

- material
- structure / morphology
- properties / characteristics

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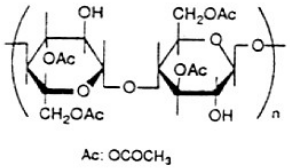
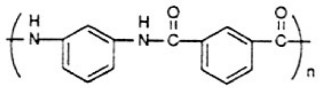
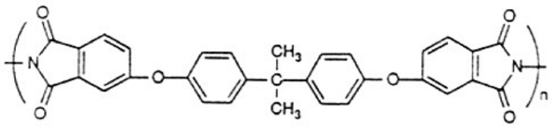
Membrane polymers:



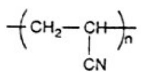
Cellulose acetate (CA)



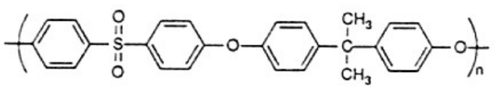
Poly(m-phenylene isophtalami(
(Normex)



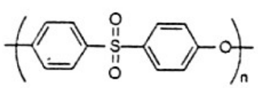
Polyetherimide (Ultem)



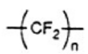
Polyacrylonitrile (PAN)



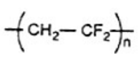
Polysulphone (PSf)



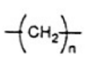
Polyethersulphone (PES)



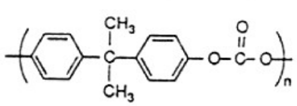
Teflon



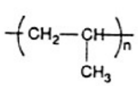
Polyvinylidenefluoride (PVDF)



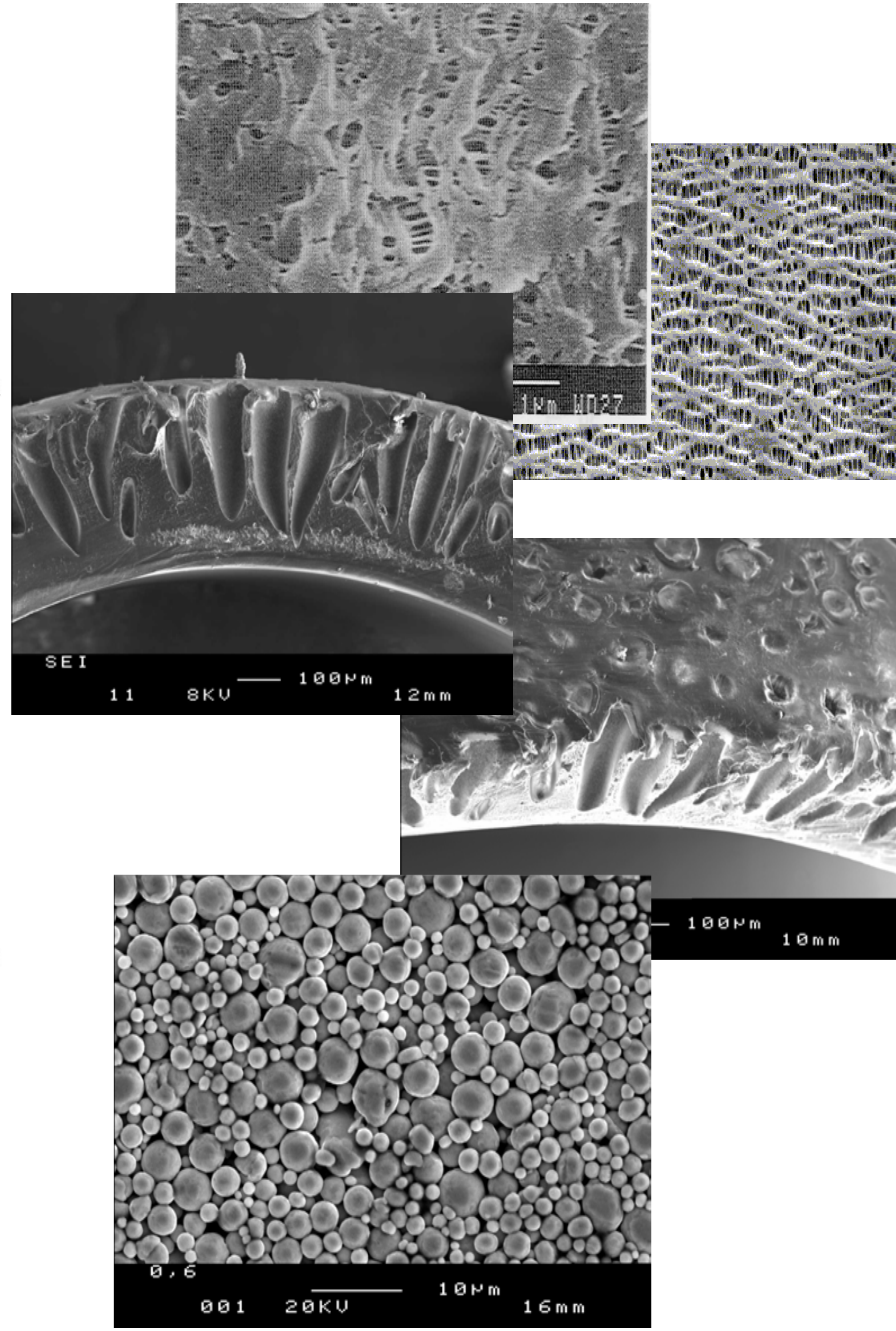
Polyethylene (PE)



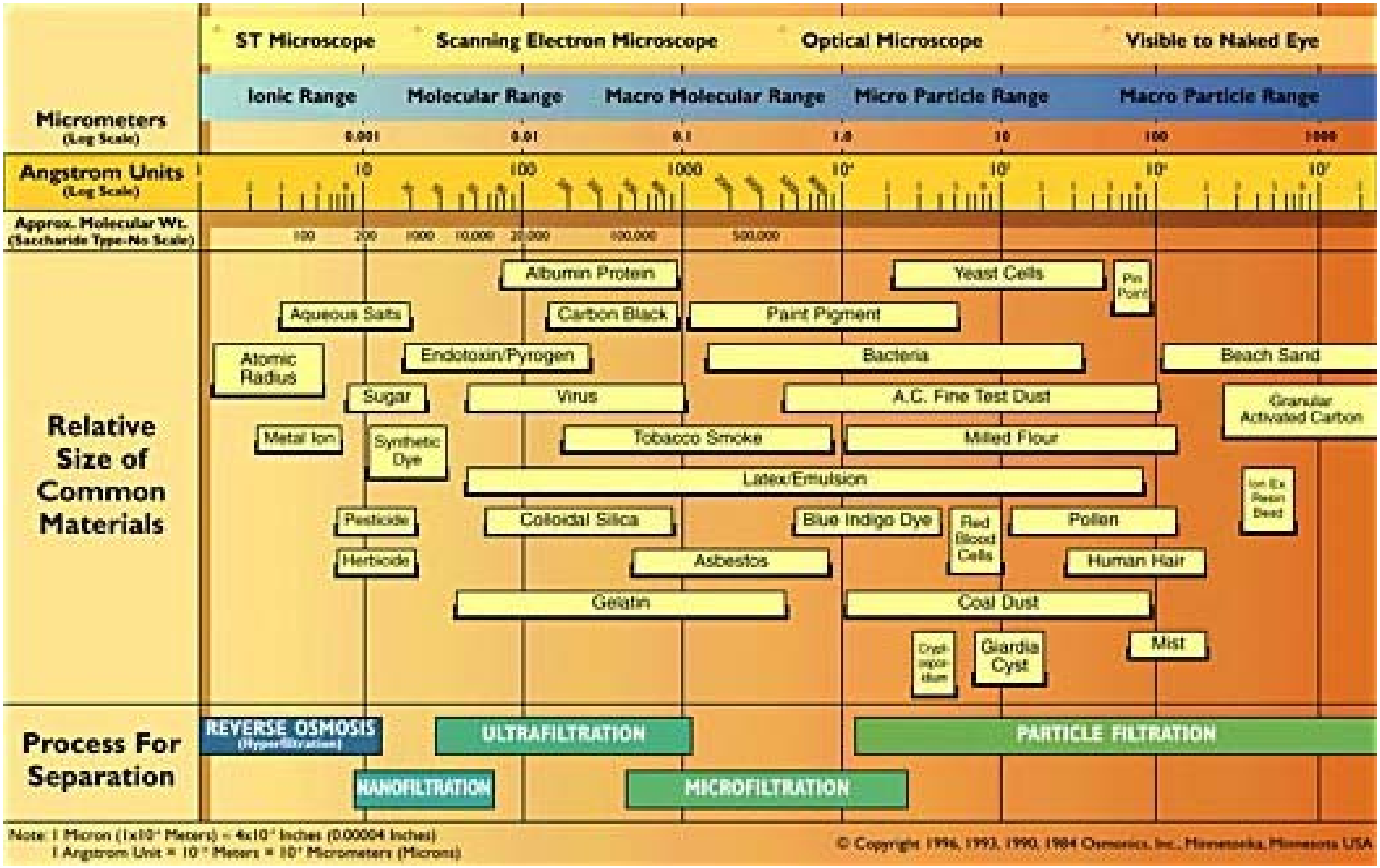
Polycarbonate (PC)



Polypropylene (PP)

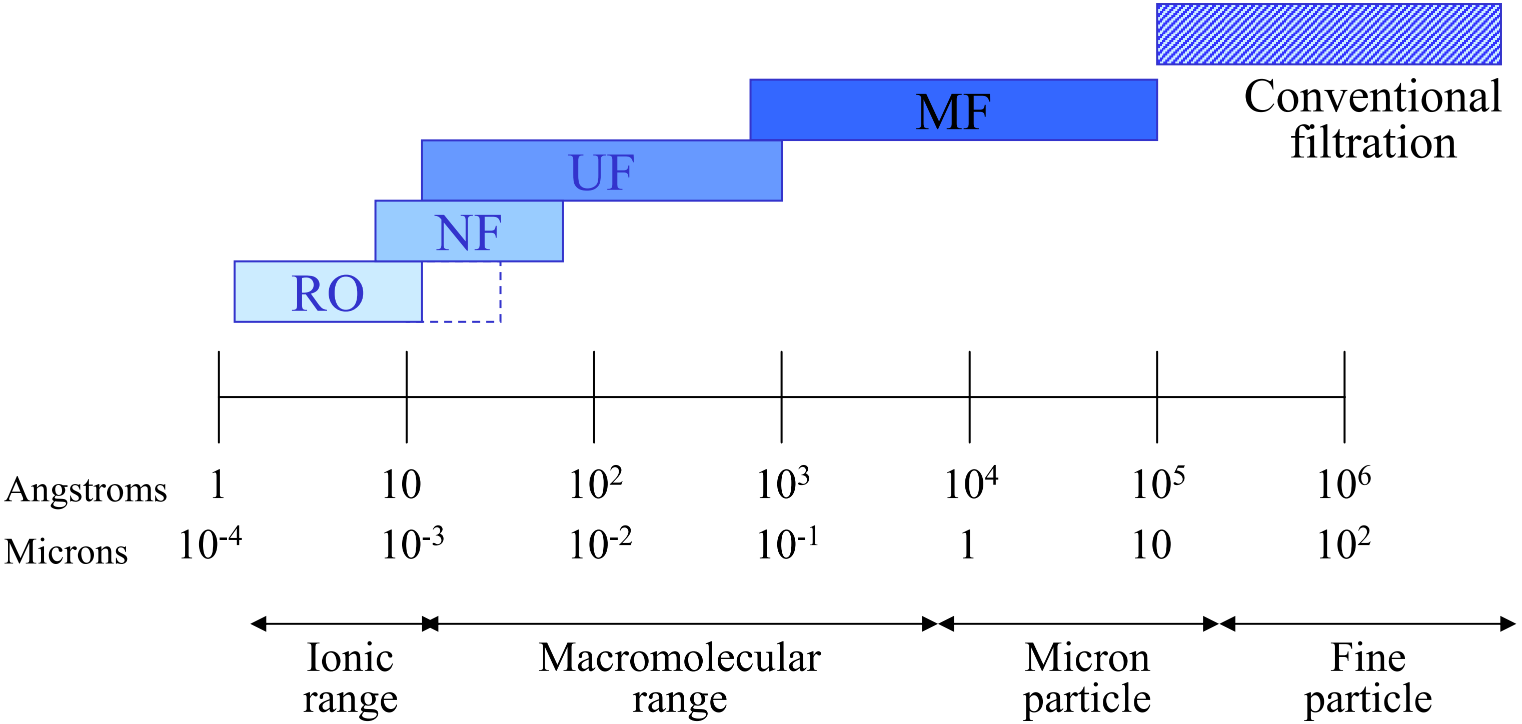


Membrane definitions: *Filtration Spectrum*



(OSMONICS)

Membrane classification:



RO – rejection of ions/solutes (< 20 Å pore size)

NF – rejection of ions/solutes (< 20 – 600 Å)

UF – defined by MWCO (10-1000 Å)

MF – colloidal suspensions (0.02 – 10 μm)

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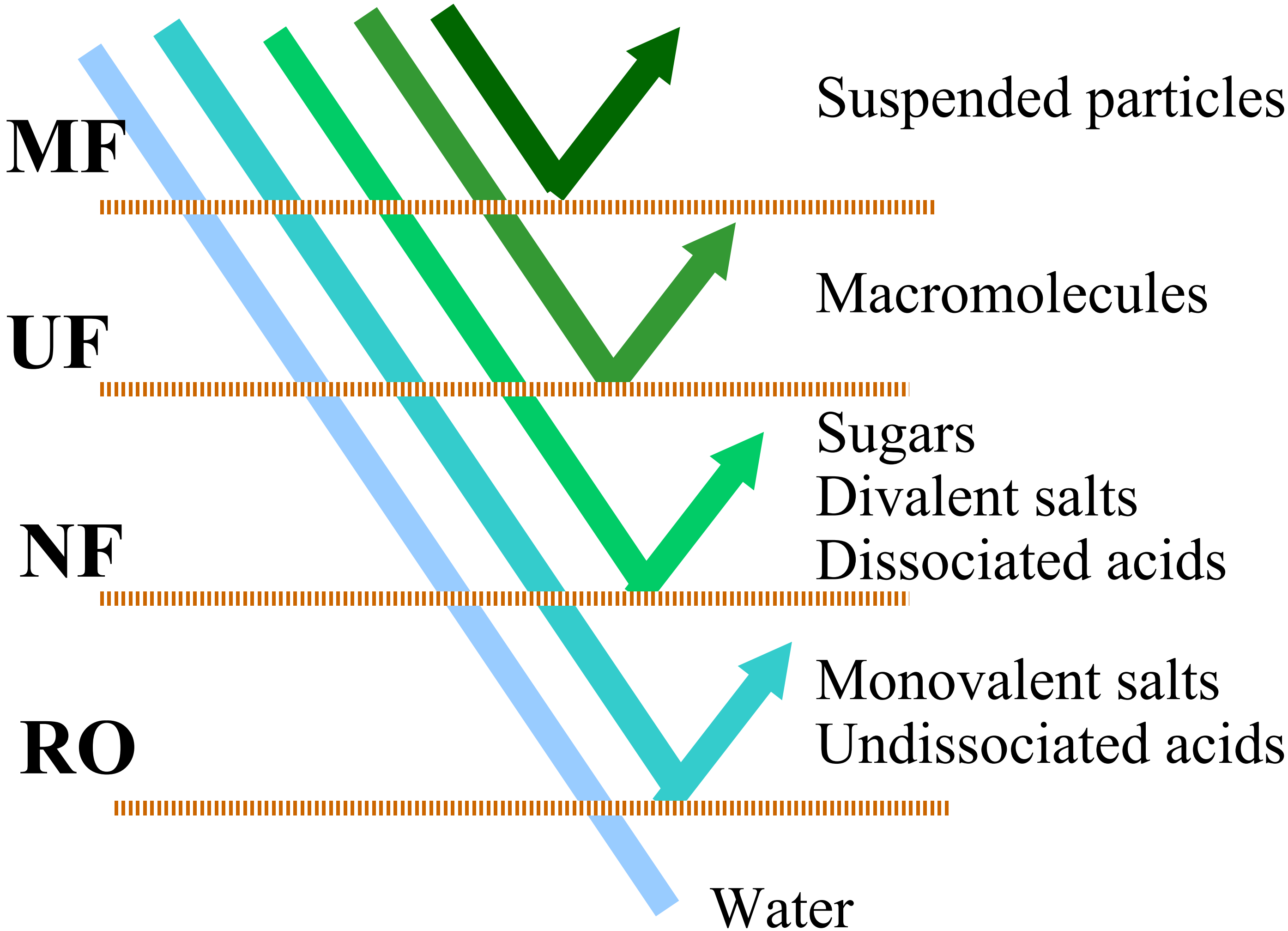
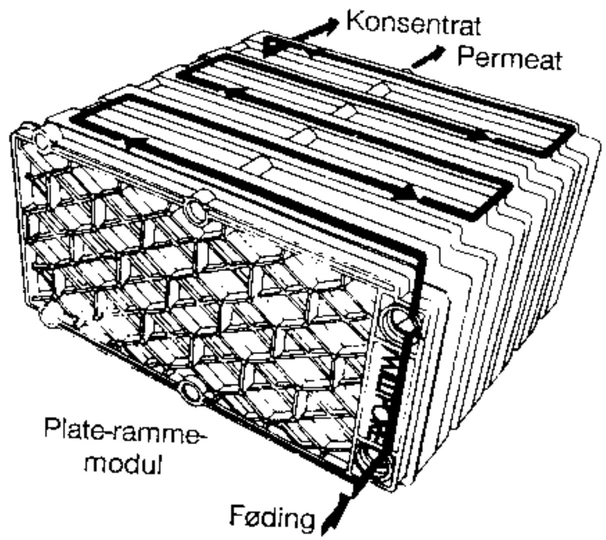
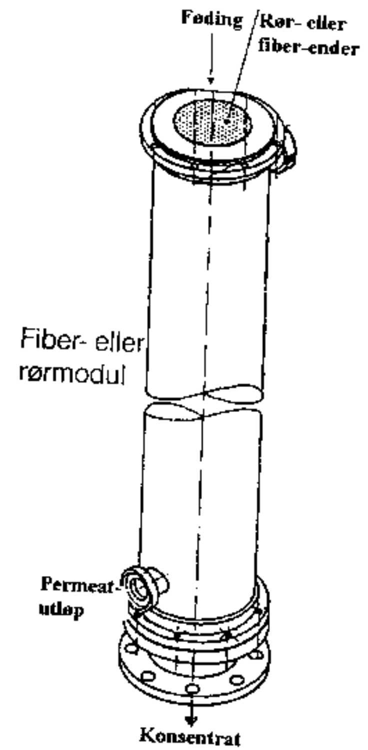
Separation characteristics:

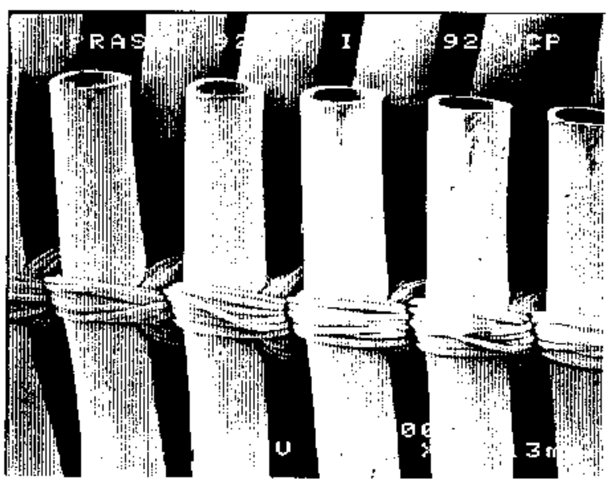


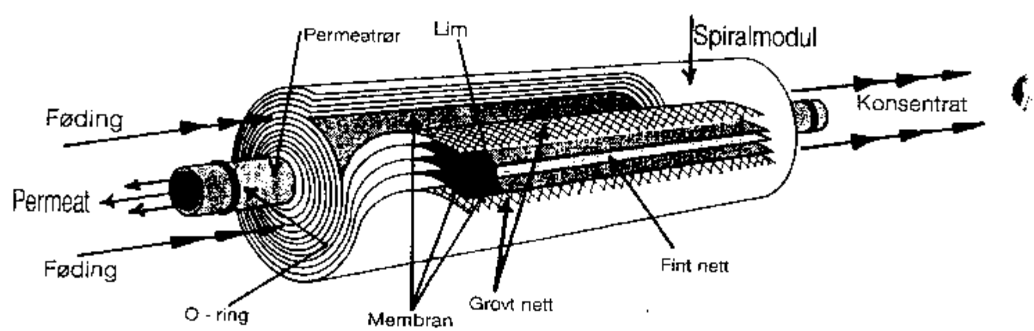
Typical membrane module configurations:

- Plate and Frame (sheets)
- Spiral wound
- Tubular
- Hollow fiber
- Fabrics









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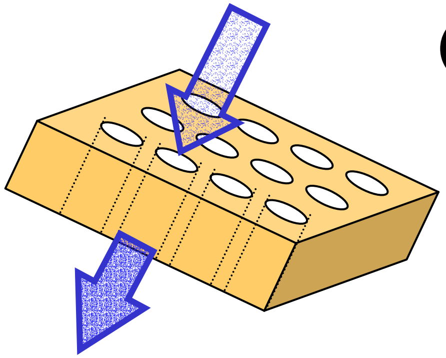
Mass transfer through a porous membrane:



Flow through a theoretical cylindrical (*Hagen-Poiseuille equation*)

$$q = \frac{\pi \cdot \Delta P \cdot d^2}{128 \cdot \mu \cdot \Delta x}$$

P - pressure

d - pore diamter

μ - viscosity

x - membrane thickness

Flux: $J = q \frac{N_p}{A}$ and $\frac{N_p}{A} \propto d^{-2} \rightarrow J \propto d^{-2}$

In general: $$J = \frac{\varepsilon \cdot r_p^2}{8 \cdot \mu \cdot \tau} \cdot \frac{\Delta P}{\Delta x}$$

ε - porosity

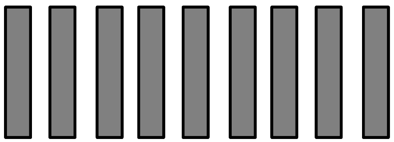
r_p - pore radius

τ - tortuosity

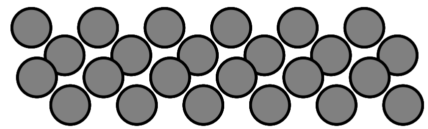
Defining flux:

? porosity / tortuosity → f (membrane properties)

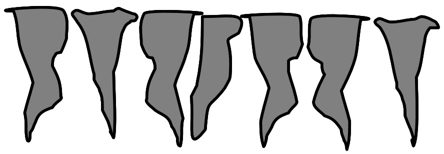
Symmetrical cylinders



Packed bed of spheres



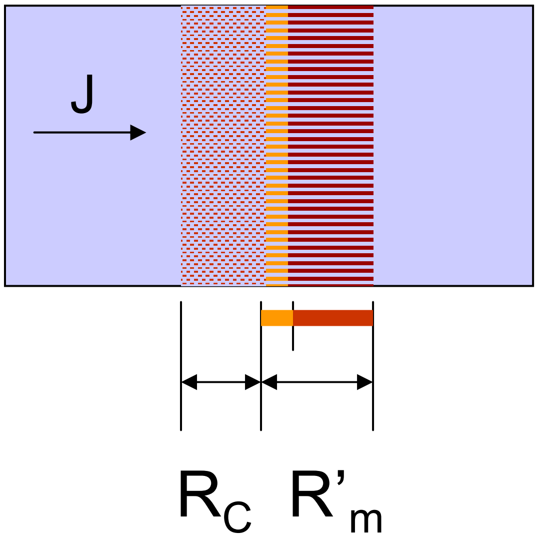
Asymmetric / sponge like



Resistance model:

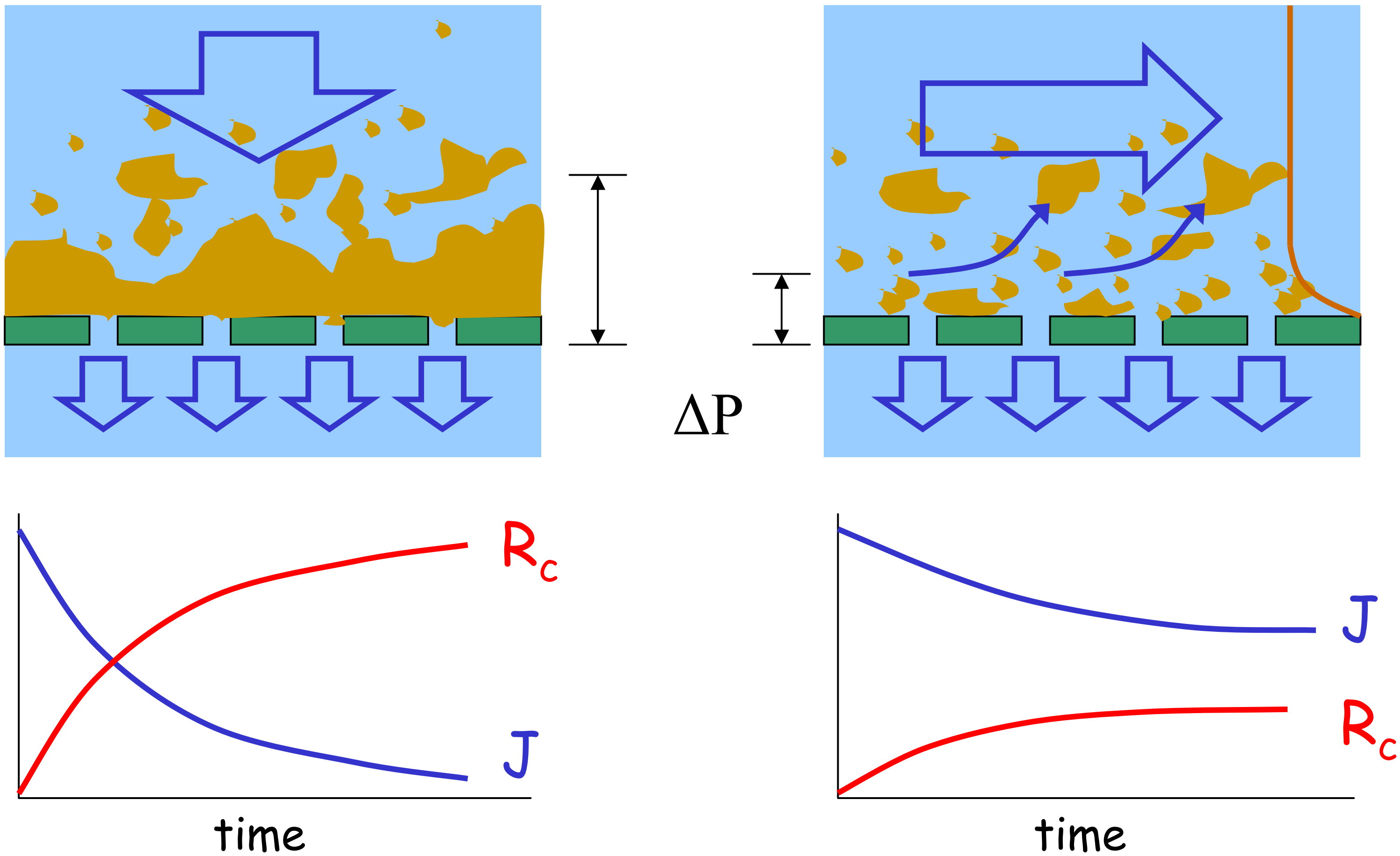
$$J = \frac{\Delta P}{R}$$

where $R = R_C + R_m^{'}$

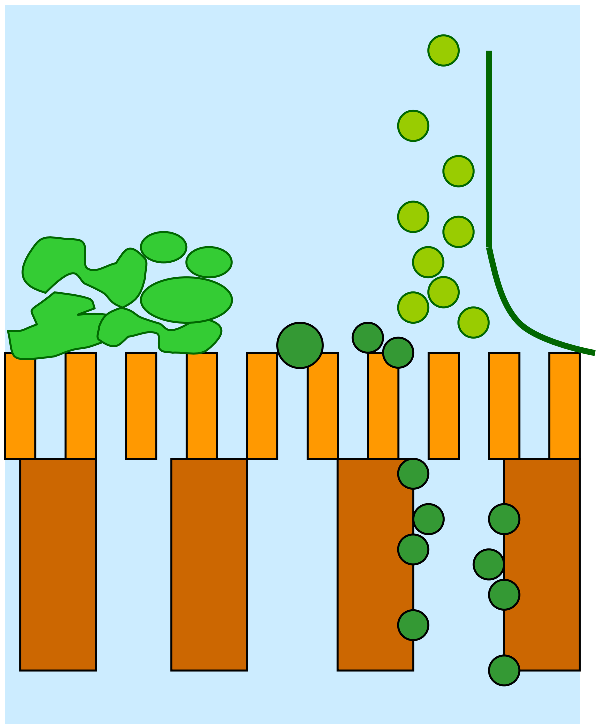


Modes of operation:

Dead-end / *Crossflow*



Defining resistance to mass transfer:



$$R = R_m + R_F + R_C + R_G + \ldots$$

1. Membrane resistance R_M:
   - determined by clean water flux
2. Fouling resistance R_F:
   - reversible / irreversible
3. Cake-layer resistance R_C:
   - dead-end operation
4. Concentration polarization R_G:
   - formation of a gel-layer

Intrinsic membrane resistance: $R_m^{'} = R_m + R_F$

$$J = \frac{\Delta P}{R_m^{'} + \Phi \cdot \Delta P}$$

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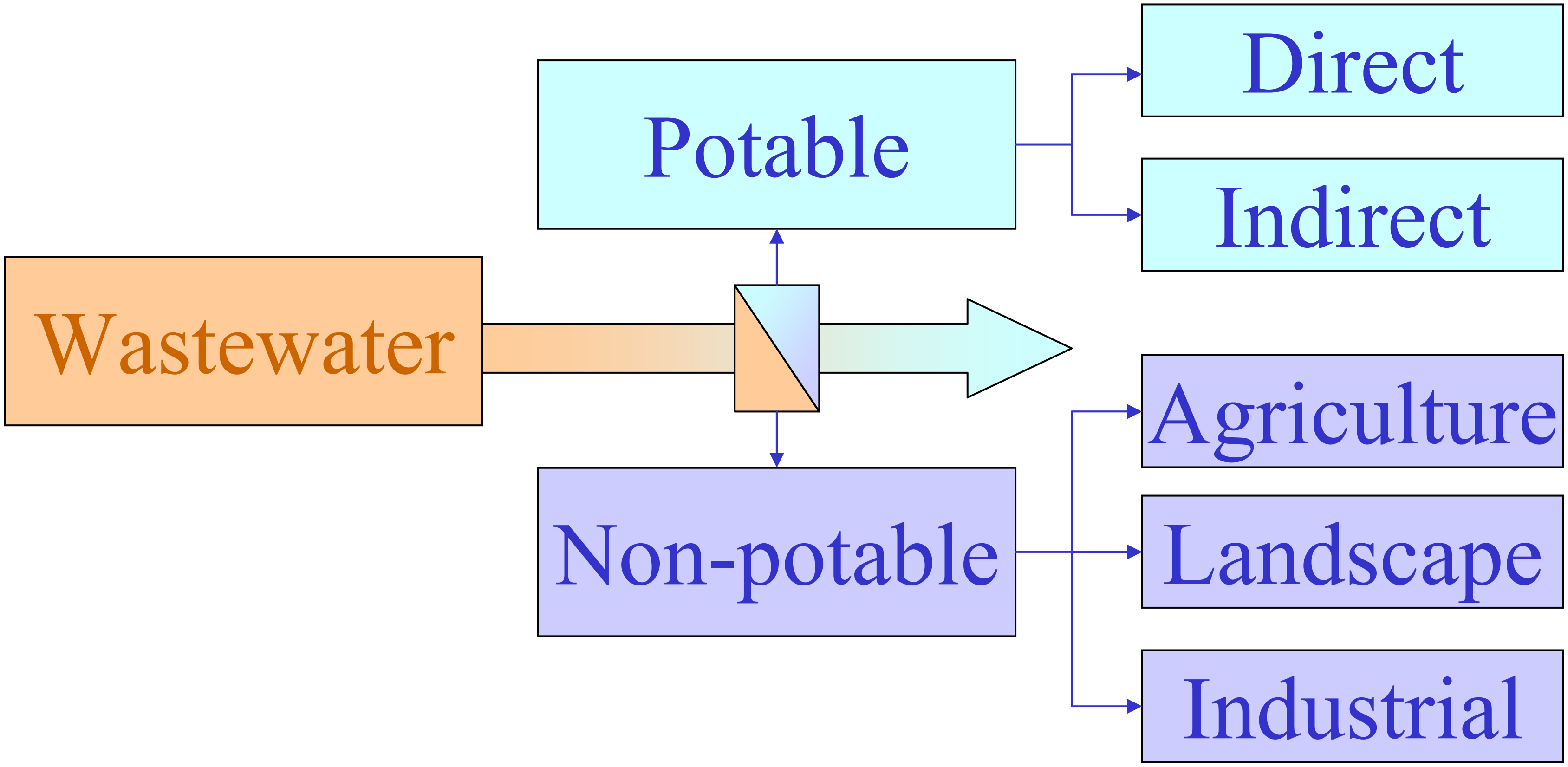
Typical performance results:

	RO	NF	UF	MF
Monovalent ions Divalent ions	> 98 % > 99 %	< 50 % > 90 %	- -	- -
Microsolutes (MW > 100) Microsolutes (MW < 100)	> 90 % 0 - 99 %	> 50 % 0 - 59 %	< 50 % -	- -
Bacteria and viruses	> 99.9 % (< 6 log)	> 99.9 % (4-6 log)	> 99.9 % (2-6 log)	95-100 % (1-3 log)
TSS mg/l Turbidity	ND ND	ND ND	100 % ND	>98 % >99 %
COD / BOD mg/l	> 99 %	> 98 %	> 95 %	> 90 %

Water reuse with membranes:



- application of recycled water
- choice of membrane process

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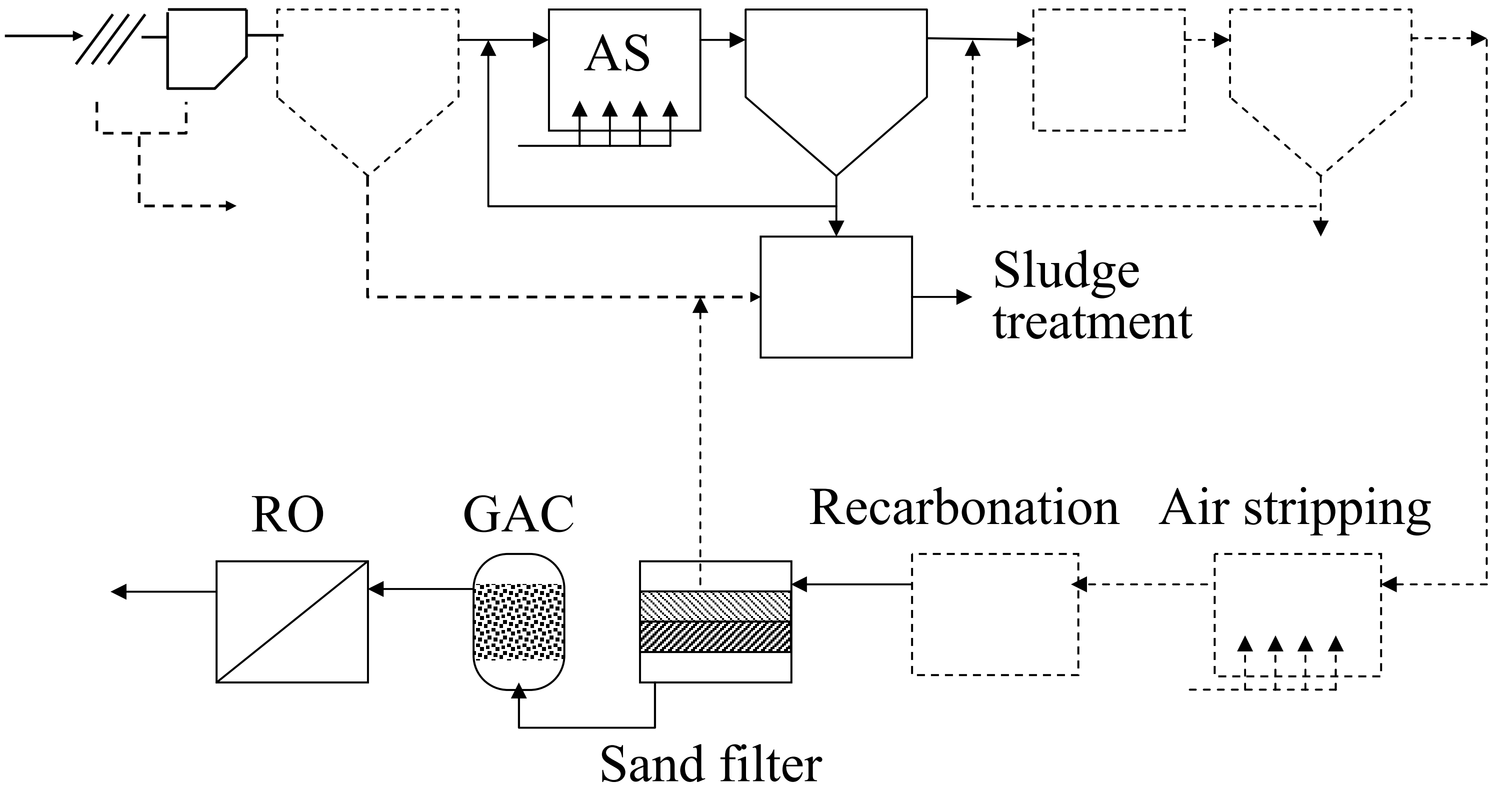
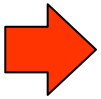
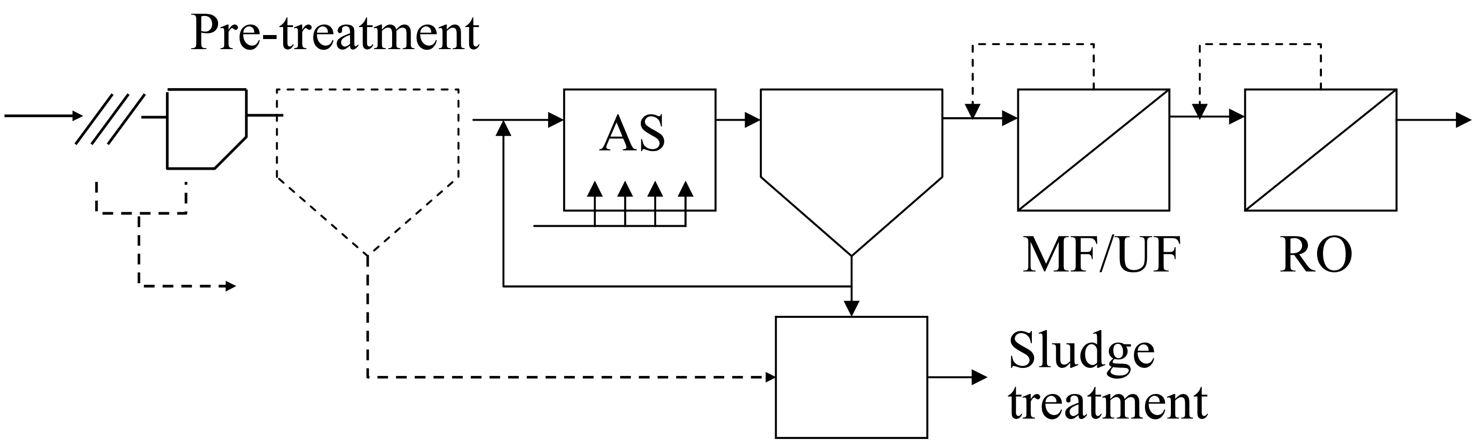
Conventional plant:





- Many unit processes
- operational restraints
- high costs

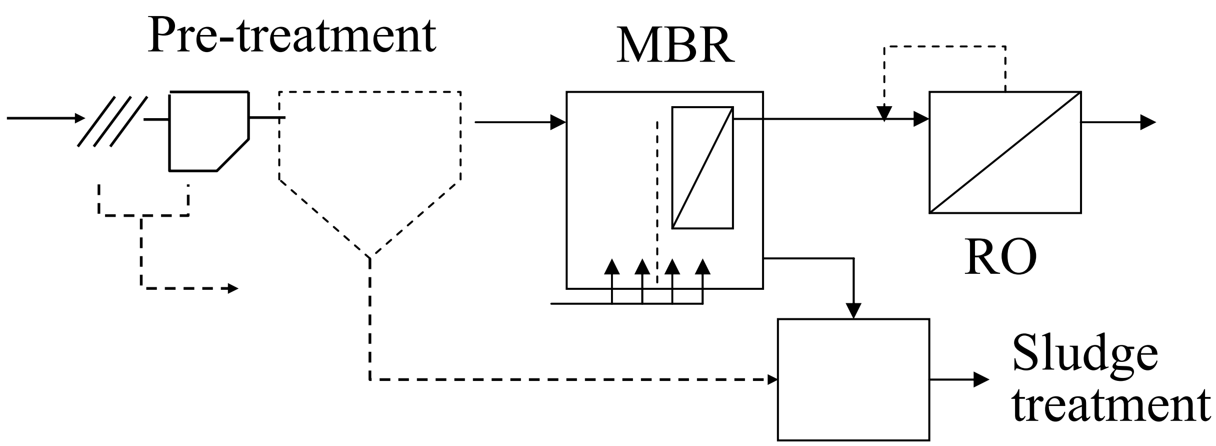
AS → MF/UF → RO:



Combines conventional process with membranes

- pretreatment of effluent necessary
- fewer unit processes
- easier to operate

MBR → RO



Hybrid solutions – 3rd generation ww treatment plants

- compact systems, less units
- high quality effluent
- easier to operate

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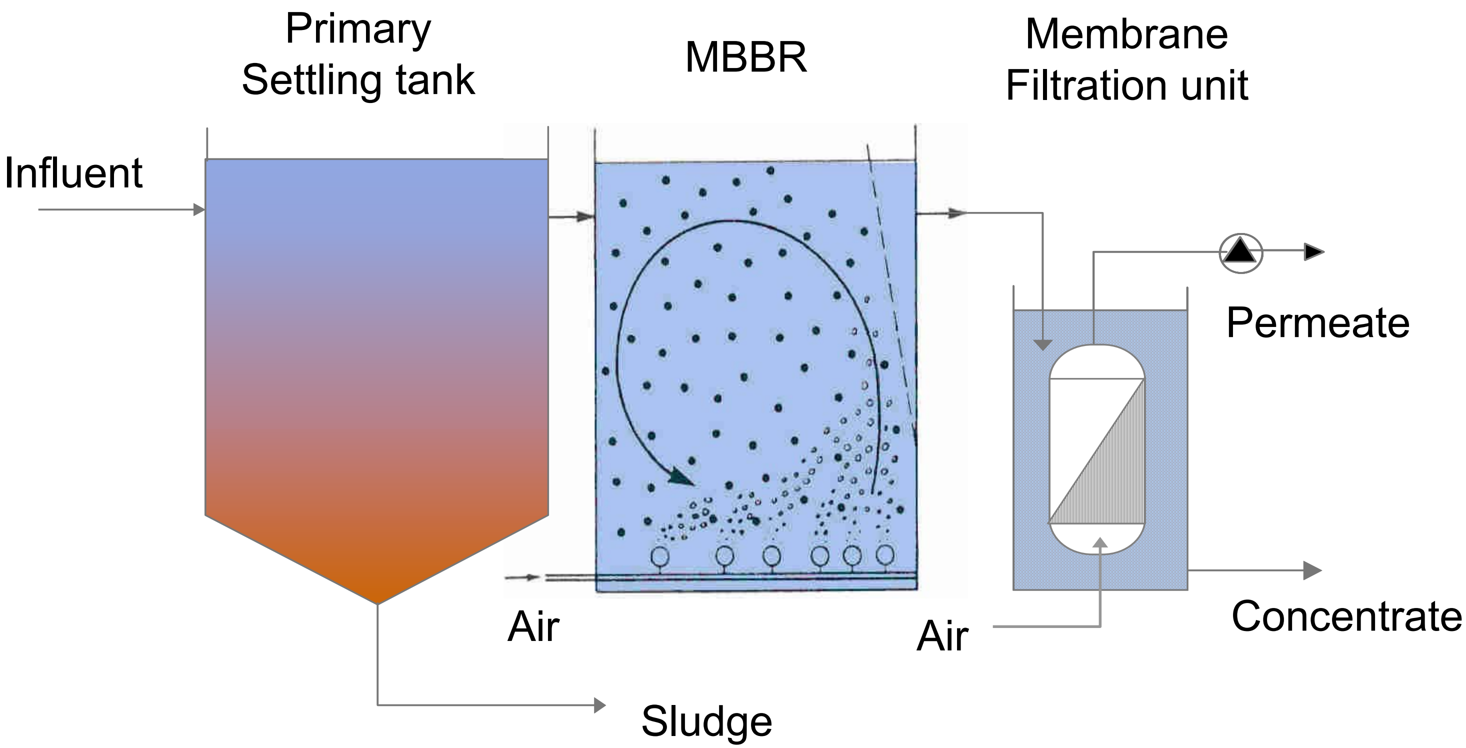
Advanced treatment study:

Investigate the potential of a hybrid process design for compact wastewater treatment plants by combining a high-rate moving bed biofilm reactor with membrane separation of biomass, colloidal and particulate COD



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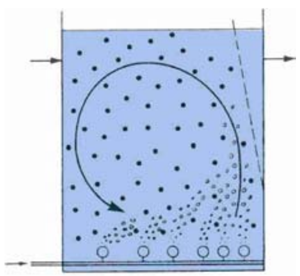
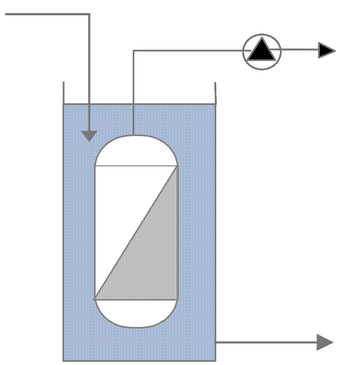
System components:

System conditions:



MBBR:

- KMT biofilm reactor	Load: 120±20 mgCOD/l
- volume: ~ 200 l	~ 40% SCOD
- flow: ~ 2 l/min	HRT ~ 100 min



Membrane filtration unit:

- membrane unit:	ZW-10, Sub. module
- configuration:	Outside/ in hollow fibers
- nominal surface area:	0,93 m^2
- process tank working volume:	190 l
- flow extracted from MBBR:	~ 1 l/min

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Influent wastewater characteristics:

	High-rate study	Membrane study
SS mg/l	88±18	79±45
COD mg/l	219±66	204±100
SCOD mg/l	100±38	56±11
NH_4-N mg/l	-	21±5
DO mg/l	4-6	2
pH	7.5±0.1	7.4±0.2
Temp. °C	10-15	14

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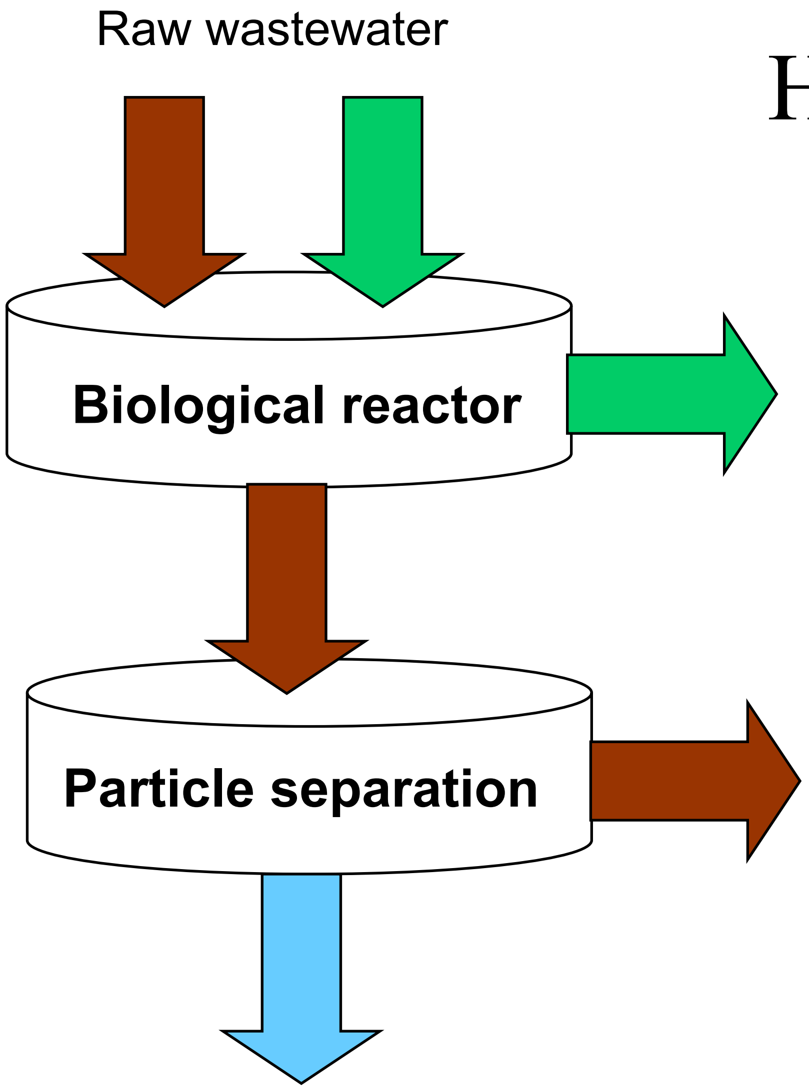
Treatment principle:



High-rate MBB-M-R

<u>MBB:</u>

- biodegradable COD
- efficient, rapid removal
- low HRT – high loading rates

<u>Membrane separation</u>

- efficient removal of particulate COD
- Flux rates, fouling
- Treatment efficiencies

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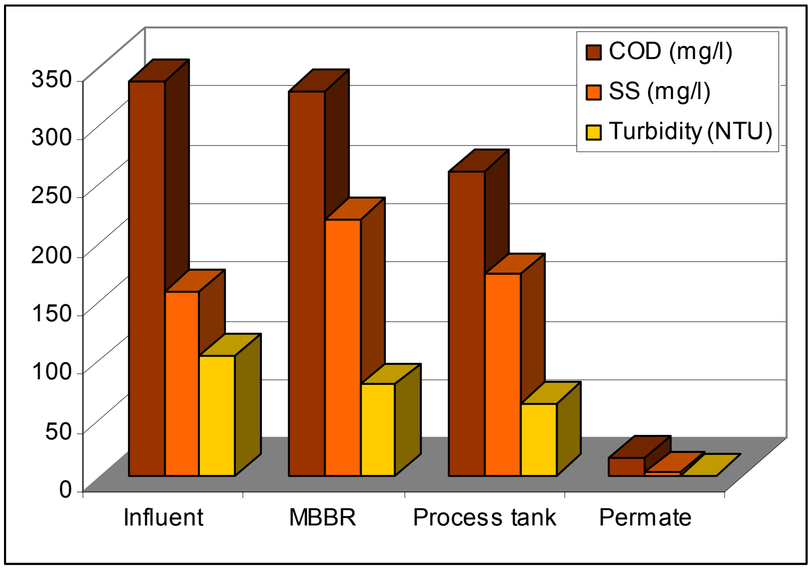
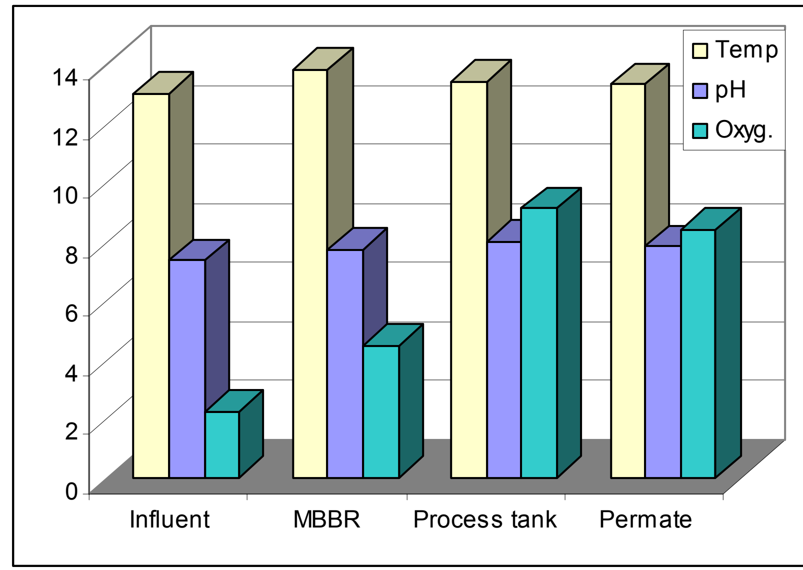
System performance:

Wastewater characteristics:





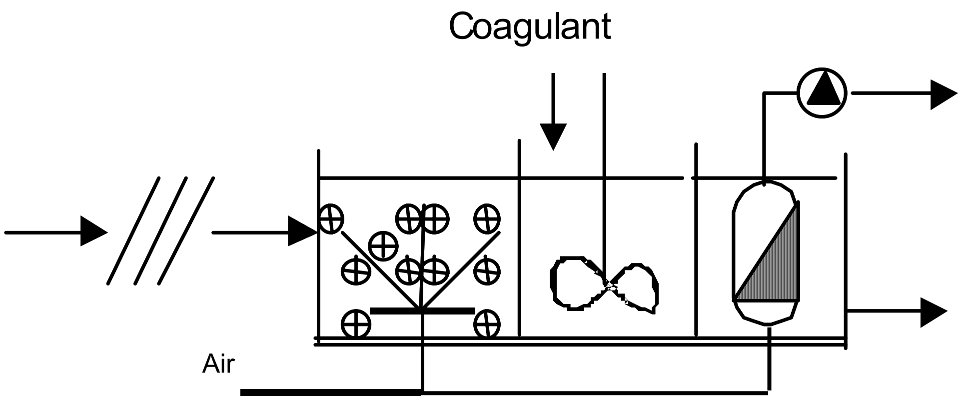
Quality parameter	SS (mg/l)	Turbidity (NTU)	COD (mg/l)	SCOD (mg/l)
Treatment efficiency (%)	99,5	99,5	84,0	24,6

Conclusions:

- Rapid removal of biodegradable COD achieved in a high-rate MBB
  - high volumetric loading rates
  - very short hydraulic retention times (HRT)

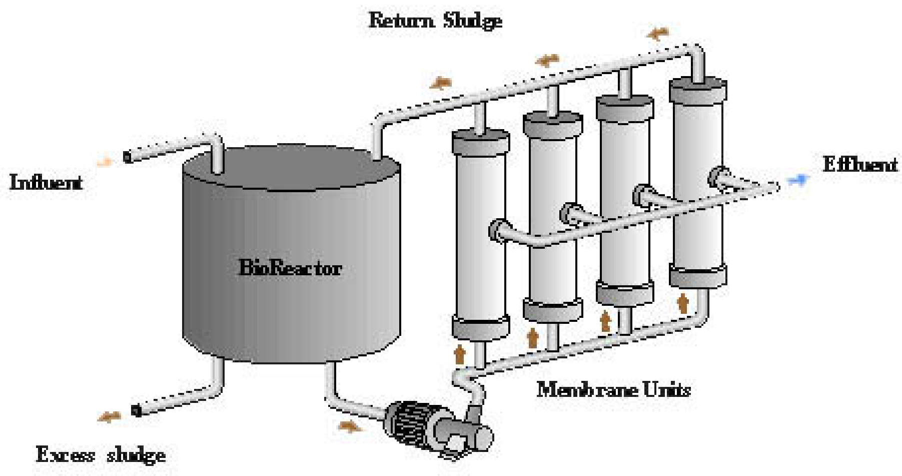
- Efficient removal of particulate COD achieved by membranes:
  - consistent high quality effluent
    (>99% removal of SS & turbidity, 80-90% removal of COD)
  - high performance maintained (flux of 60 LMH)

Concept:



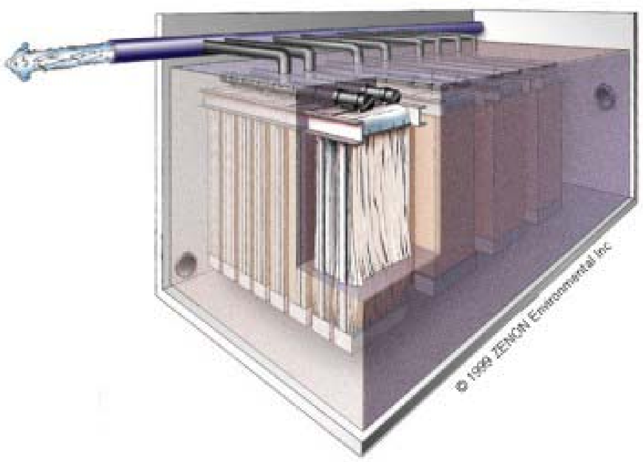
MBB-M-R

Reclamation and reuse of wastewater:



External unit

Submerged unit



Membrane technology is the accepted solution and BAT for wastewater reclamation and reuse!