Latest Membrane Technologies in Industrial Water & Wastewater treatment

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Membranes & Water Treatment

Membranes are used for various applications

- ü Surface water treatment
- ü Groundwater treatment
- ü Recycling
- ü Wastewater treatment
- ü Water reuse
- ü Sea water desalination
- ü Polishing

Membranes - Based on Pore Size

Microfiltration (MF):	0.15 to 50 micron
Ultrafiltration (UF):	0.003 to 0.2 micron
Nanofiltration (NF):	0.001 to 0.003 micron
Reverse Osmosis (RO):	0.0005 micron

Micro Filtration

Ø Simple screening mechanism

Pore size 0.1 • m - 1 • m

ΔP ≈ 0.1 to 5 bar

Ø Low pressure process

Ø Most effectively remove particles and microorganisms (bacteria)

Ø High flux

Ø Colloids/Macromole pass through

Ultra Filtration

Ø Screening and Adsorption

Pore size 0.01 • m - 0.1 • m

ΔP 1 - 10 bar

Ø Membrane is classified in terms of Molecular Weight-Cut off (MWCO) : 1000 - 100,000

MWCO	Approx. pore size (nm)
1,000	2
10,000	5
100000	12
1000,000	28

Two layers: a thin (0.1 to 0.5 µm), skin layer and Porous substructure support layer

Ø Separation of macromolecules

Ultra-Filtration

Relation between MWCO and the pore size for UF membranes.

	Pore Diameter		
MWCO (Daltons)	µm	nm	Å
1000000	0.1	100	1000
500000	0.02	20	200
100000	0.01	10	100
50000	0.004	4	40
10000	0.0025	2.5	25
5000	0.0015	1.5	15

Nano-Filtration

Ø NF removes molecules in the 0.001 • m -0.01 • m range

ΔP: 5 - 60 bar

MWCO: 200 to 1000

Ø NF is essentially a lower-pressure version of reverse osmosis

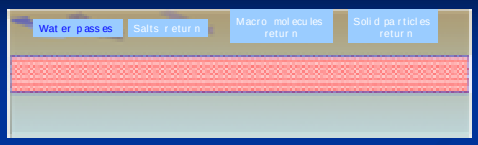
Ø NF performance characteristics : Between Reverse Osmosis and ultra-filtration

Ø NF removal of bivalent ions, removal of organic compounds, dyes

Nano-Filtration

- Membrane filtration to separate different fluids or ions
- Used in applications where high organic removal and moderate inorganic removals desired
- Cabaple of concentrating sugars, divalent salts,bacteria,proteins, particles, dyes and other consistuents that have a molecular weight greater than 1000 daltons

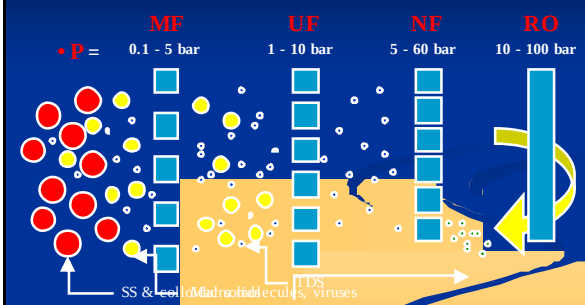
Reverse Osmosis



Operating Pressure: 10 - 100 bar

RO has the separation range of <0.001 •m

Membrane Processes

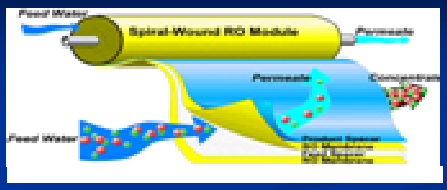


Membrane Classification - Modules

Membrane module refers to the device which houses the membrane element:

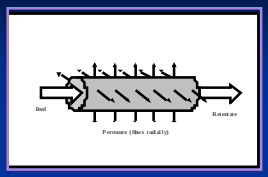
- Tubular membrane module
- Hollow fibre membrane module
- Spiral wound membrane module

Spiral Wound Membrane Module



- Flexible permeate spacer is provided between two flat sheet membranes
- Membrane: sealed three side and open side is attached to perforated pipe
- Flow is in a spiral pattern.
- Membrane envelop is spirally wound along with a feed spacer
- Filtrate is collected within the envelop and piped out

Tubular Membrane Modules



- Membrane is cast inside the support tube
- Tubular membranes have a diameter of 5 - 15 mm
- High SS tolerance
- Flow is usually inside out
- Mainly MF and UF
- Low packing density, high prices per module

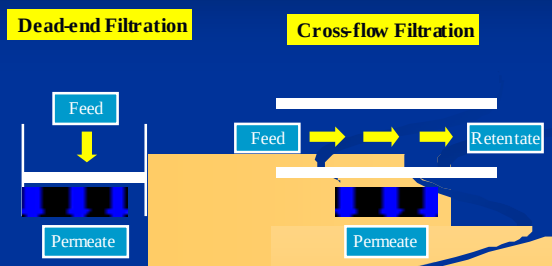
Hollow Fibre Membrane Module

- Ø Consists of a bundle of hundreds and thousands of hallow fiber
- Ø Entire assembly is inserted into a pressure vessel
- Ø Feed can be applied inside of the fiber (inside-out flow) outside (outside-in flow)
- Ø Highest packing density of all.
- Ø Hollow fiber is used mainly for NF and RO

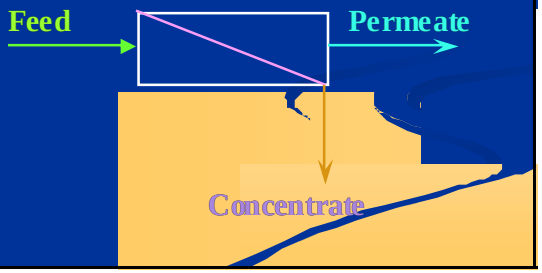
Membrane Materials

- Ø Asymmetric cellulose acetate
- Ø Polyamides
- Ø Polyacrylonitrile (PAN)
- Ø PVC/PAN copolymers
- Ø Polysulphone
- Ø Sulphonated polysulphones
- Ø PVDF (polyvinylidene difluoride)
- Ø PES (polyethersulfone)
- Ø Substituted PVA

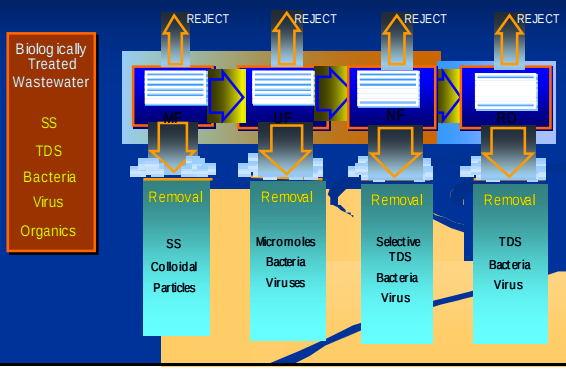
Cross Flow Vs. Dead End Filtration



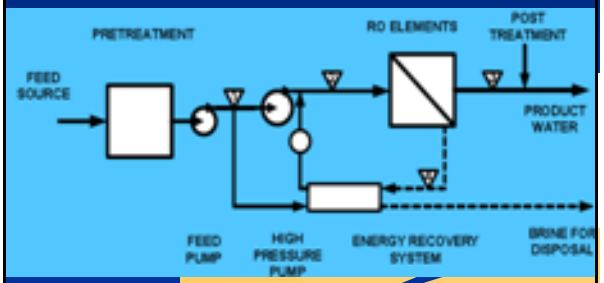
Membrane Process



Membranes - Water Recycling Applications



Components of a RO System



RO Desalination

- Product recovery from 30 % to 90 % of the feed flow
- Required pressure:
  - 7 to 13 bar for normal water (TDS upto 5000 mg/l)
  - 17 to 27 bar for brackish water (TDS upto 12000 mg/l)
  - 54 to 80 bar for seawater (TDS upto 50,000 mg/l)

Reverse Osmosis

Design considerations

- Feed Water Quality & Pre-treatment
- Choice of membranes, design flux, recovery, array
- Choice of chemicals
- Membrane cleaning
- Composition and quantity of reject

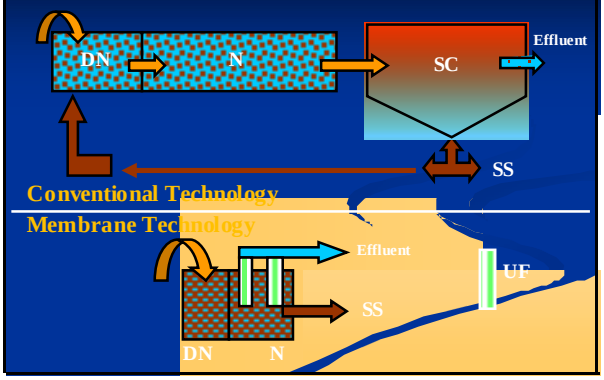
Reverse Osmosis

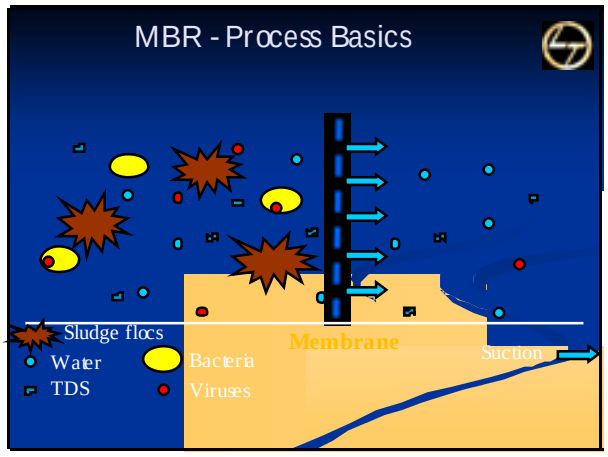
Feed Water Limiting Parameters

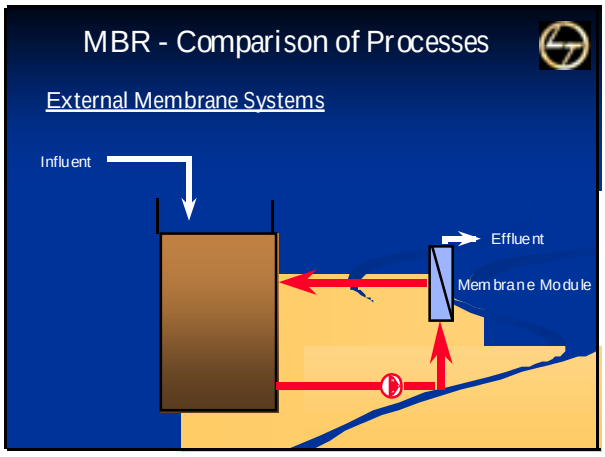
Limiting Parameter	Value
PH	3 – 10
Temperature	< 45 degrees Celsius
Turbidity	< 1.0 NTU
Silt density index	< 4.0
Oil & grease	Nil
Free chlorine	< 0.1 mg/l, continuous
Fe, Mn	< 0.1 mg/l, total

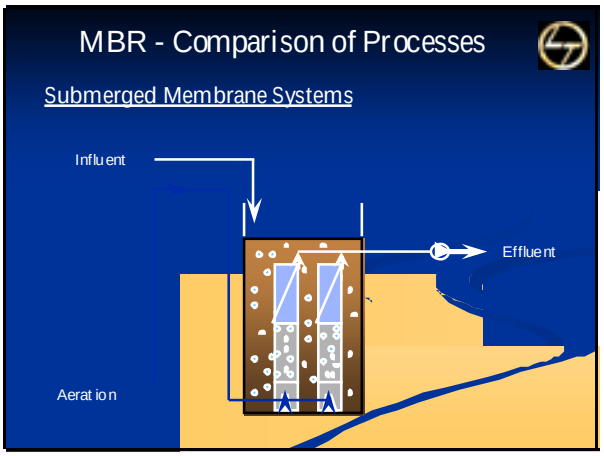
Membrane Bio-Reactor

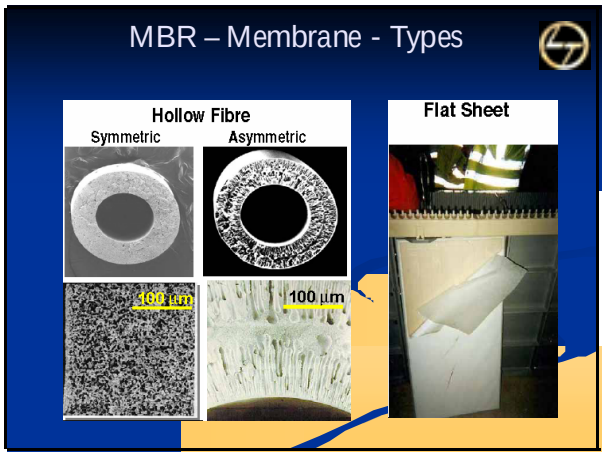
MBR - Process Basics




MBR - Process Basics
Sludge flocs
Water
TDS
Bacteria
Viruses
Membrane
Suction


MBR - Comparison of Processes
External Membrane Systems
Influent
Effluent
Membrane Module


MBR - Comparison of Processes
Submerged Membrane Systems
Influent
Effluent
Aeration


MBR – Membrane - Types
Hollow Fibre
Symmetric
Asymmetric
100 µm
100 µm
Flat Sheet

Conventional ASP vs. MBR

Treatment	Conventional Activated Sludge	MBR Process
Final Clarifier	Yes	No
Tertiary Filter	Yes	No
MLSS (mg/L)	< 4,000	>10,000
Sludge Age (day)	< 10	>10
Footprint	Large	3 – 5 times smaller
Process Stability	Sensitive to sludge bulking	Not sensitive to upsets

MBR - Effluent Water Quality

Membrane provides an absolute barrier and effluent quality is no longer a concern

Parameter	Conventional	MBR
TSS, mg/l	<30	<2
Turbidity, NTU	2-10	<0.2
Total Coliform number per 100ml	10,000-100,000	< 100
BOD_5, mg/l	<20 to 30	<2

Assessment of MBR Technology

Advantages

- High effluent quality
- No sludge settling problems
- Lower footprints & volumes

Disadvantages

- Membrane fouling
- Complex controls
- Higher capital &
- Increased operational costs

Membrane Operation - Key Factors

- Flux
- Fouling
- Rejection
- Recovery
- Temperature - Viscosity of Water

Membranes - Incremental Developments

Better Membranes

- Longer life
- Low pressure required
- High salt rejection
- Lower cost

Changes in Water Pricing

- Commodification of water pricing
- Water for industries is costly
- Large scale sea water RO cost approx Rs. 40/ m3
- Recycled and desalinated water - Competitive with other sources of water

Reclamation of Water

- Wastewater as a source of raw water
- Reclaimed water is much cheaper – capital cost as well as operating cost
- Many countries recycle and reuse up to 70 percent of their wastewater
- Direct and indirect reuse possible

Thank you

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