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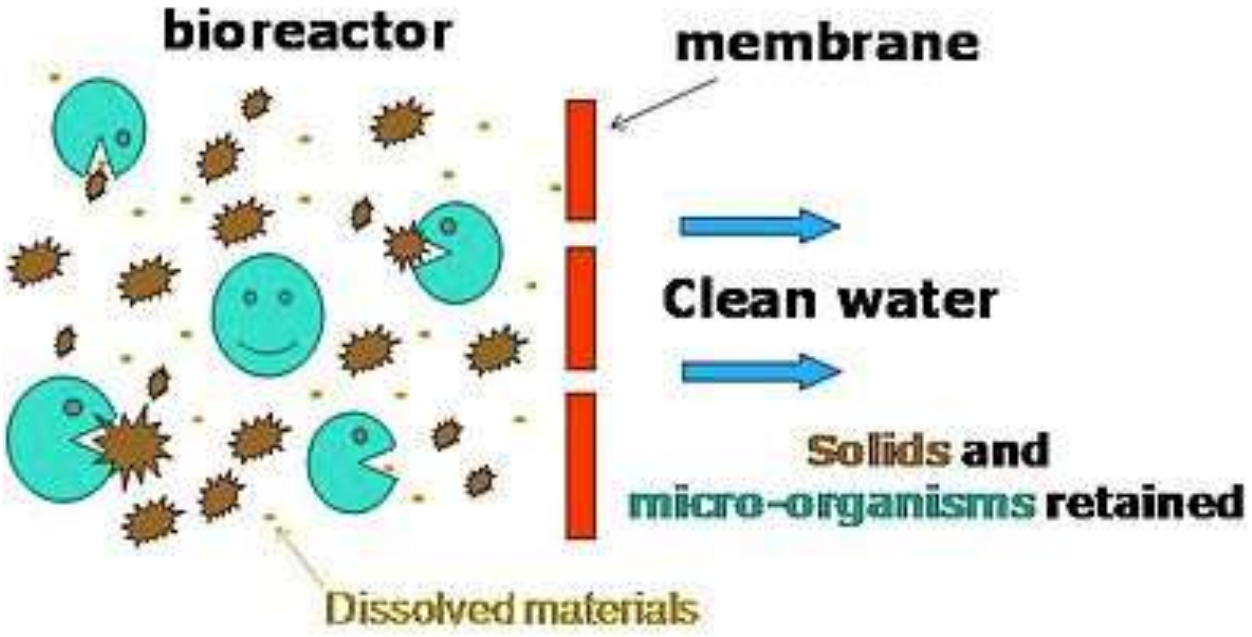
Webinar section:

Approach to the development of a Cleaner & Greener Environment through a new wastewater treatment technology MBBR & MBR

Fundamentals of MBR for wastewater treatment

Guest Speaker:
Assoc.Prof. Dang Thi Thanh Huyen, HUCE

MBR DEFINITION



- MBR is an abbreviation of Membrane BioReactor

- MBR is composed of two processes:
  + Biological process (conventional activated sludge
  + Filtration using microfiltration or ultrafiltration membranes

- In the MBR process, membranes act as a solid-liquid separation device, keeping the biomass within the bioreactor. Basically, they take the place of clarifiers used in the conventional activated sludge (CAS) process

FILTRATION BY MEMBRANE

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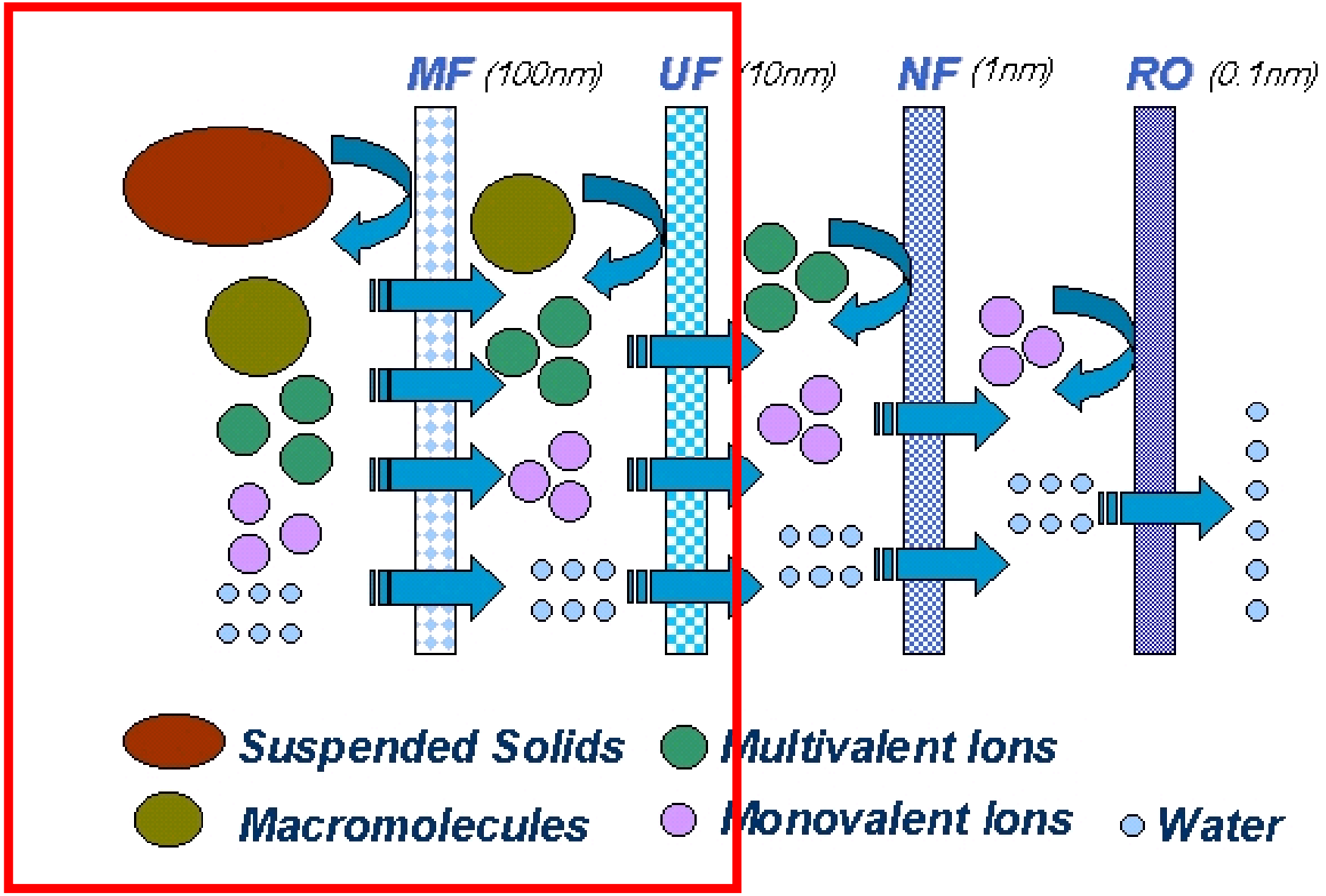

MEMBRANE CONFIGURATION

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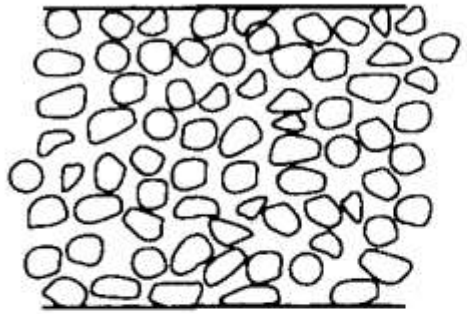
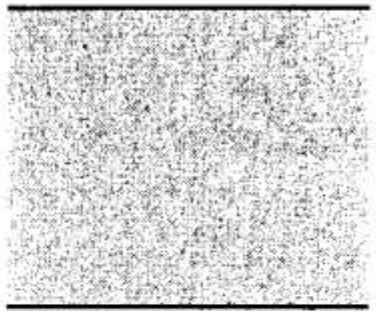
Symmetrical membrane

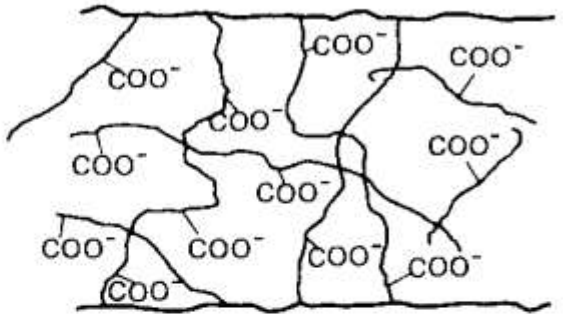
Isotropic microporous membrane



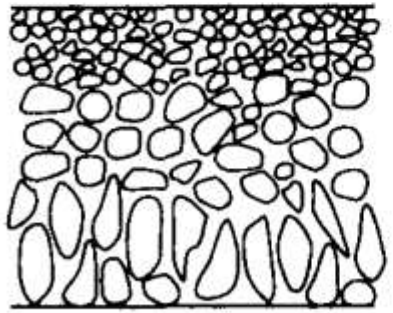
Non-porous dense membrane



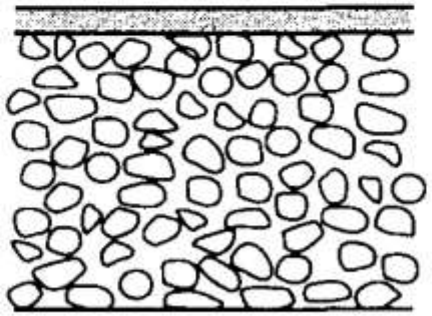
Electrically charged membrane



Anisotropic membranes

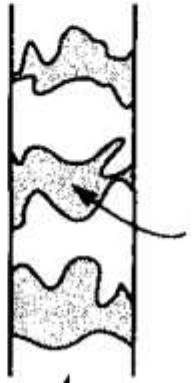


Loeb-Sourirajan anisotropic membranes



Thin film composite anisotropic membranes

Supported liquid membrane



Liquid filled pores

filled pores

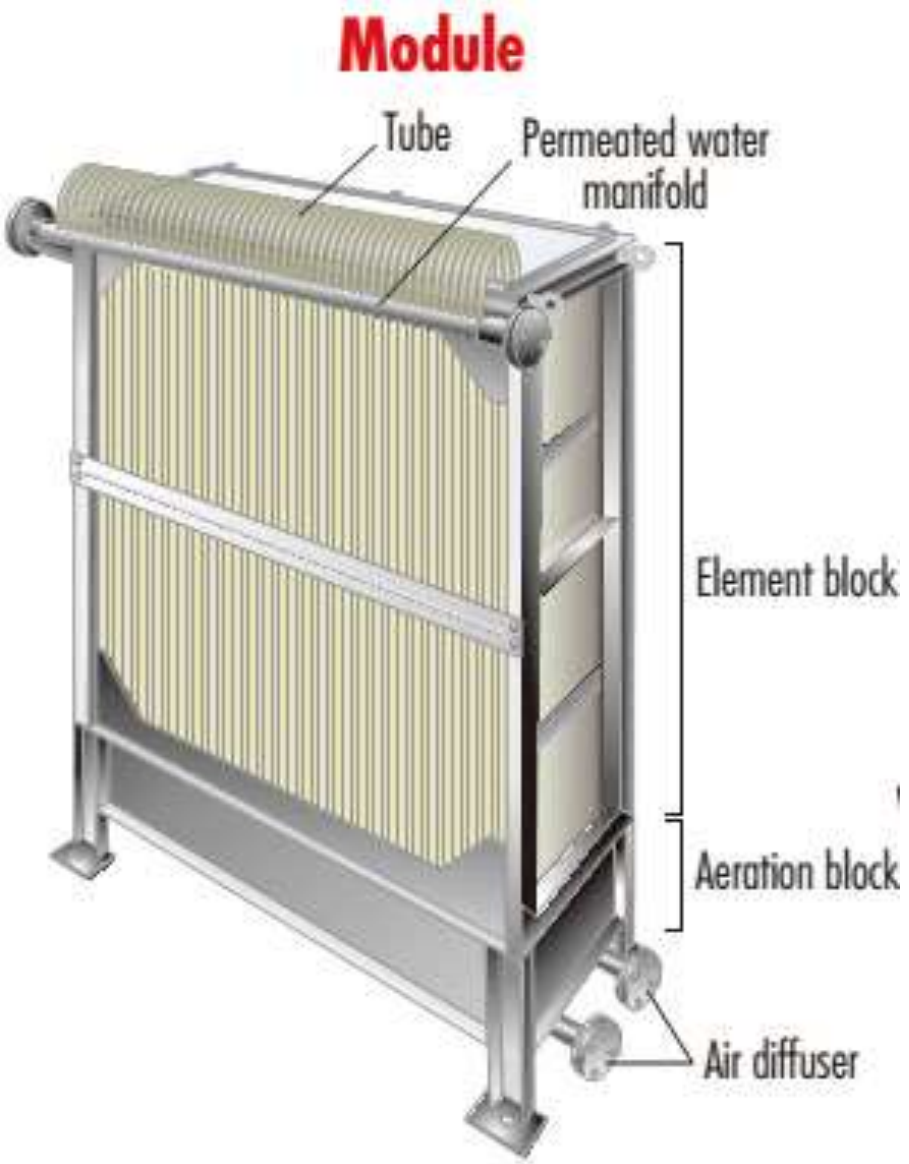
Polymer matrix

MICROFILTRATION MEMBRANE

- Membrane type: Isotropic microporous membrane
- Pore size: 0.05 - 5 μm
- TMP: 0.1- 2 bar
- Filtration rate: >0.5 m3/m2.d.bar
- Separation mechanism: screening
- Materials: Polymer, fiber, ceramic
- Application: Water and wastewater treatment

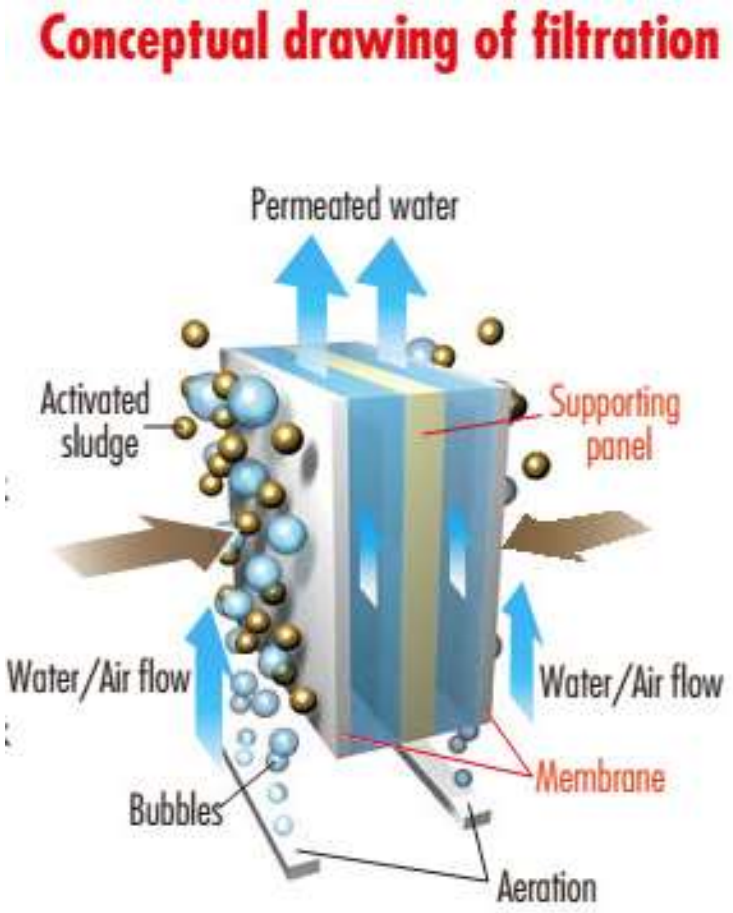
ULTRAFILTRATION MEMBRANE

- Membrane type: Isotropic microporous membrane
- Pore size: 0.01-0.1 μm
- TMP: 1-10 bar
- Filtration rate: >0.1-0.5 m3/m2.d.bar
- Separation mechanism: screening
- Materials: Polymer, fiber, ceramic
- Application: Water and wastewater treatment



MEMBRANE TYPES

PLATE AND FRAME MEMBRANE



MEMBRANE TYPES

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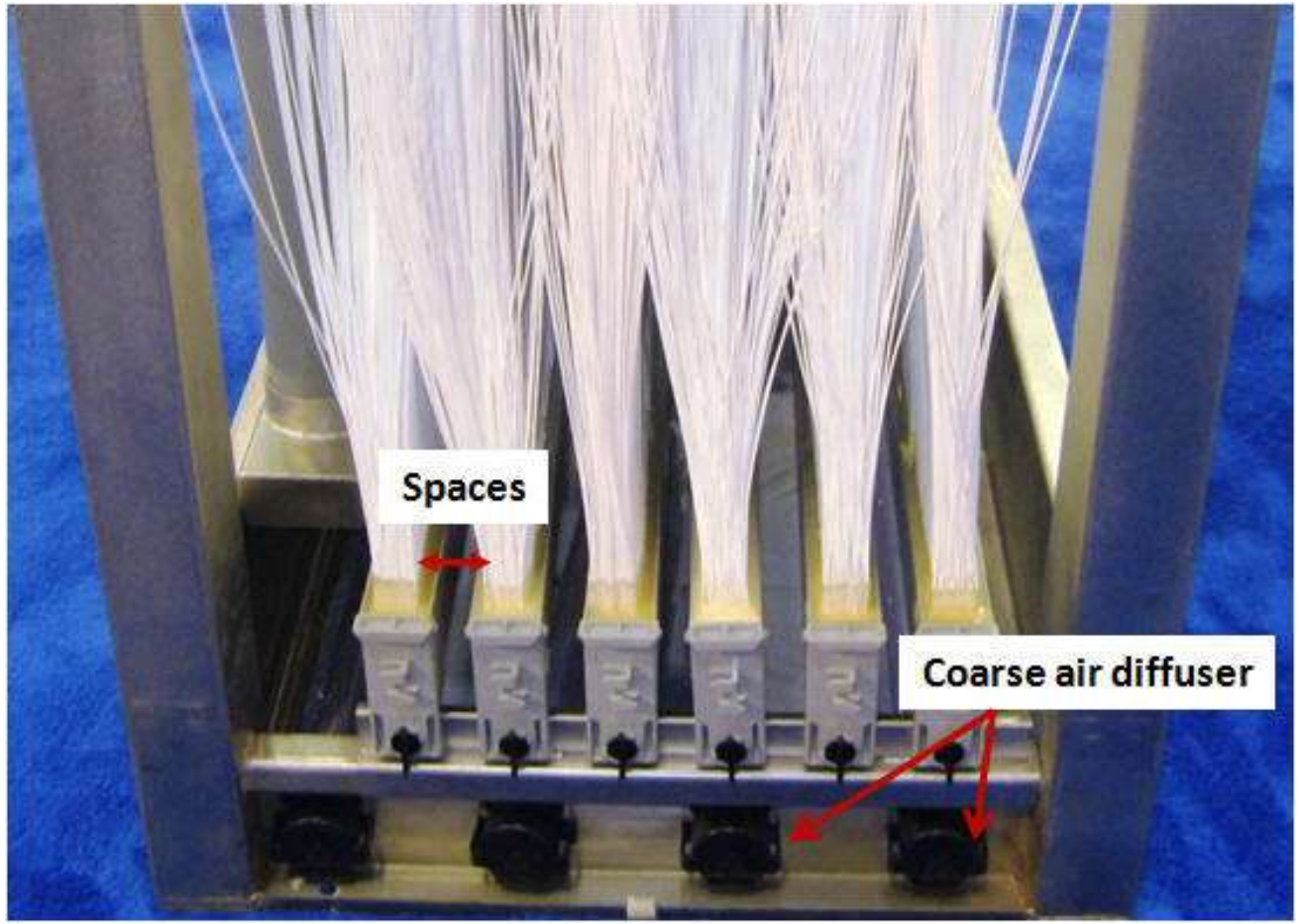
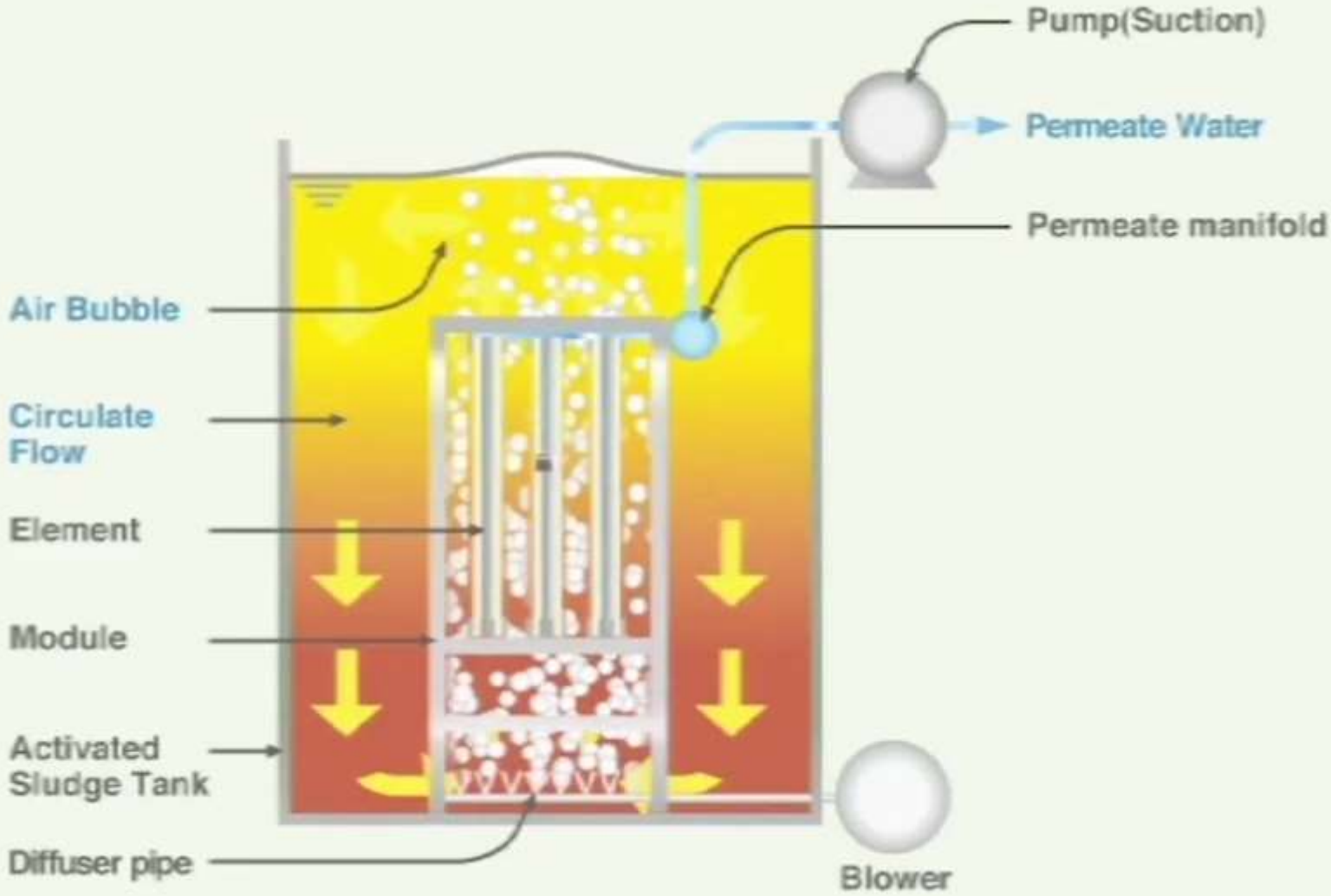
HOLLOW FIBER MEMBRANE




Pump(Suction)
Permeate Water
Permeate manifold
Air Bubble
Circulate Flow
Element
Module
Activated Sludge Tank
Diffuser pipe
Blower

'TORAY'

MEMBRANE TYPES

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TUBULAR MEMBRANE

MEMBRANE TYPES

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Investment:

Hollow fiber, Plate and frame < Tubular

Contaminant loading:

Hollow fiber < Plate and frame < Tubular

Durability:

Hollow fiber < Plate and frame , Tubular

Pretreatment requirement:

Hollow fiber > Plate and frame > Tubular

Cleaning frequency:

Hollow fiber > Plate and frame > Tubular

(Nguồn: Krzeminski, P và các cộng sự (2012) Desalination and Water Treatment, 42 (1-3):100-106)

MBR SYSTEM CONFIGURATION

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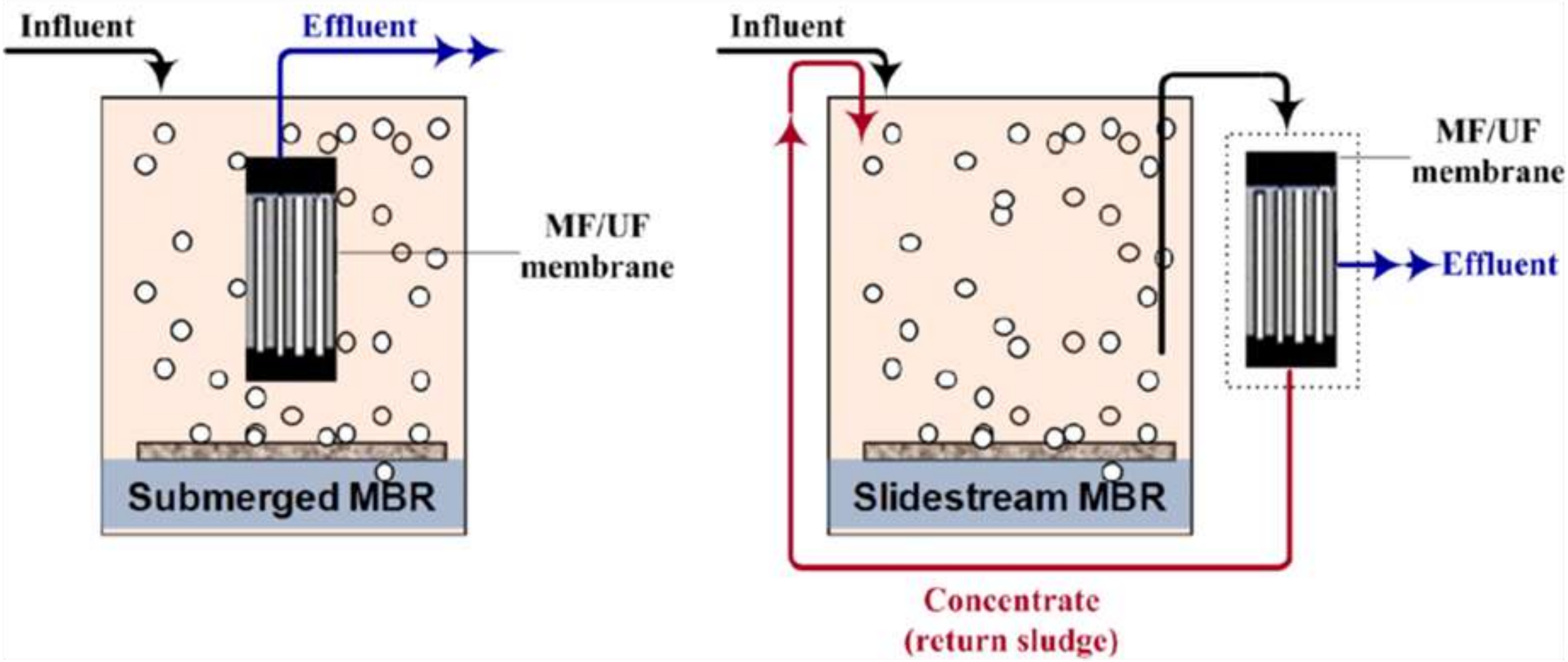

MBR SYSTEM CONFIGURATION

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COMPARISON OF SUBMERGED/IMMERSED AND SIDE-STREAM MBR SYSTEMS

Item	Unit	iMBR (immersed)	sMBR (side stream)
Typical configuration	-	Hollow fiber (HF) Flat sheet (FS)	Tubular (TB) Plate&Frame (PF)
Mode of operation		Crossflow	Crossflow
Operating pressure	kPa	5 – 30 (vacuum)	300 – 600
Long-term Average Flux	LMH (m/d)	15-35 (0.36-0.84)	50-100 (1.2-2.4)
Permeability[1)]	LMH/kPa	0.5-5	0.07 - 0.3
Recycle ratio	m^3 feed/m^3 permeate	-	25-75
Superficial velocity	m/s	0.2-0.3[5)]	2-6
	m^3 air/m^3 permeate	7 – 30[6)]	-
SED[2)]	kWh/m^3 permeate	0.1-0.5	4-12
Membrane cost[3)]	$/$m^2$	<50	>1,000
Capital cost		Low	High
Operating cost		Low	High
Cleaning	-	Hard	Easy
Odor/VOC emission potential	-	High	Low
Packing density		Low	High
Market Share[4)]	-	99%	1%

WHY MBR?

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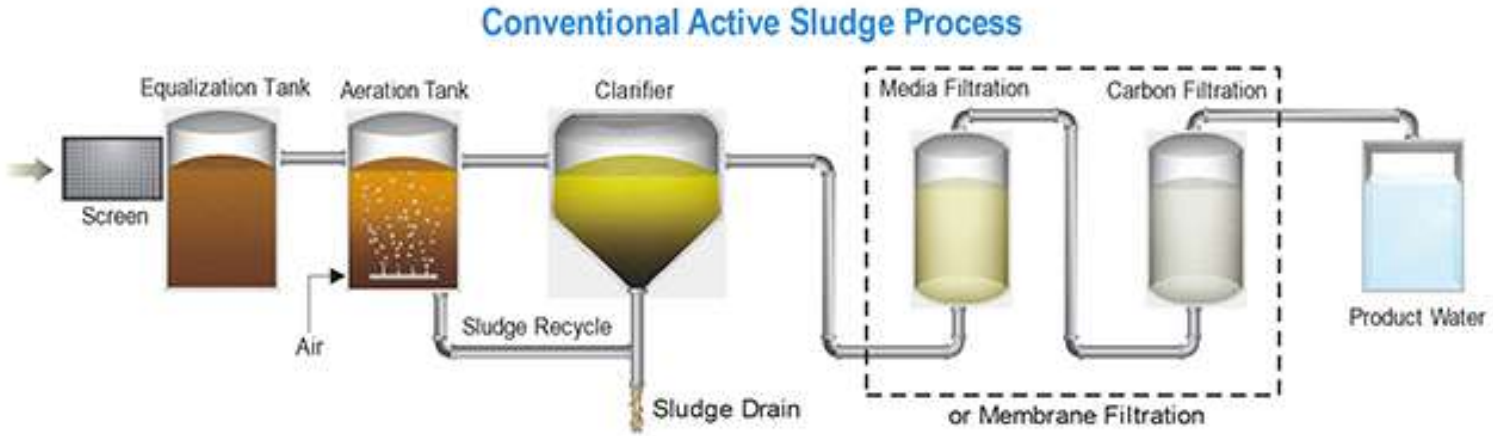
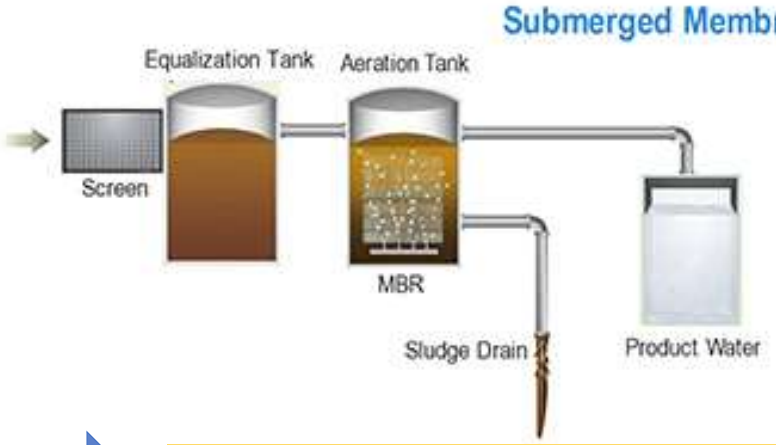
COMPARISON OF MBR AND CAS





ADVANTAGES

- Smaller footprint
- Superior quality product water
- Lower total installed cost

The removal of secondary clarifiers and the operation of MBR at a lower HRT result in significantly reduced plant area requirements

WHY MBR?

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COMPARISON OF MBR AND CAS - domestic wastewater treatment

Parameters	CAS (Aerotank + Secondary Clarifier)	MBR
Hydraulic retention time, HRT (h)	6 - 12	4 - 6
Sludge retention time, SRT (days)	Several days	>15 days
MLSS (mg/L)	2000 - 6000	8000 - 25000
Sludge generation	More	Less
Secondary Clarifier	Yes	No

WHY MBR?

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Type of wastewater	HRT (h)
Domestic wastewater (WW)	4 - 6
Food processing WW	10 - 20
Chemical industry WW	24 - 48
Aquatic industry wastewater	10 - 20

WHY MBR?

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COMPARISON OF MBR AND CAS - effluent quality

Parameters	CAS	MBR
BOD_5 (mg/L)	10 – 30	<5
TSS (mg/L)	10 – 30	<1
TN (mg/L)	5 - 10	<3
TP (mg/L)	4 - 8	<0.1
Turbidity (NTU)	5 - 20	<0.2
Fecal Coliform (MPN/100 ml)	5 - 20	<2

WHY MBR?

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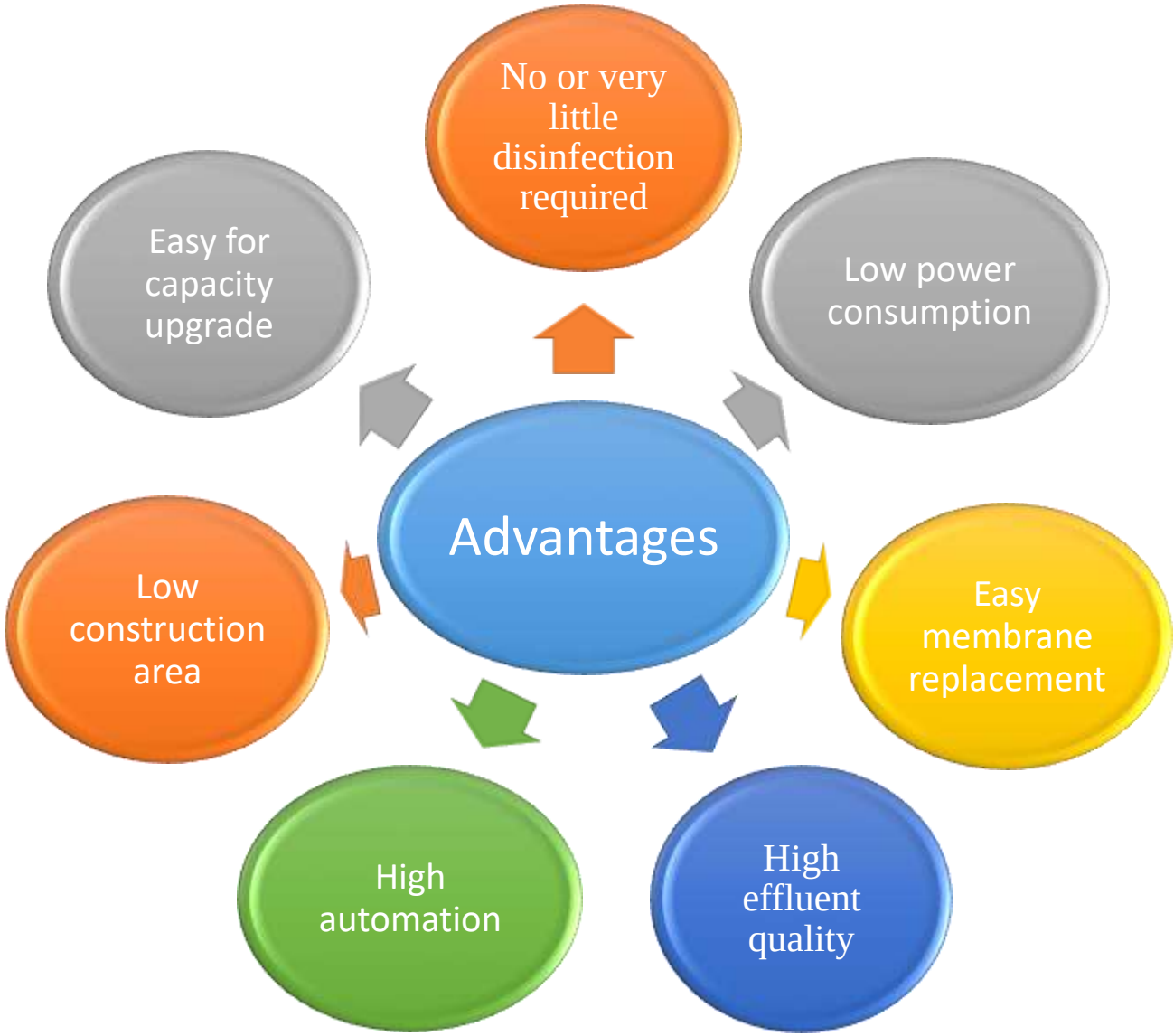
Installation	Location	Technology supplier	(Expected) Commissioning date	PDF (MLD)	ADF (MLD)
Tuas Water Reclamation Plant	Singapore	TBC	2025	1200	800
Beihu WWTP	Hubei, China	Beijing Origin Water (BOW)	2019	1040	800
Henriksdal, Sweden	nr Stockholm, Sweden		Stage 1: mid 2019 / Stage 2: 2021 / Stage 3: 2023 / Stage 4: 2026	864	536
Huaifang Water Recycling Project	Beijing, China	Memstar	2016	780	600
Water Affairs Integrative EPC	Xingyi, Guizhou, China	Beijing Origin Water (BOW)	2016–2017	399	307
Seine Aval	Acheres, France		2016	357	224
Canton WWTP	Ohio, USA	Ovivo	2015–2017	333	159
9th and 10th WWTP	Kunming, Yunnan, China	Beijing Origin Water (BOW)	2013	325	250
Wuhan Sanjintan WWTP	Hubei Province, China	Beijing Origin Water (BOW)	2015	260	200

LIST OF LARGEST MBR PLANTS IN THE WORLD

The global capacity provided by MBR technology at the time of writing (2019) is probably somewhere over 20 GLD (gigalitres per day). 1 GLD = 1.000.000 m3/d
Given that around 1000 GLD of sewage is being generated globally, and that perhaps only half of this is treated, it can be estimated that MBR technology provides around 5% of the world's sewage treatment capacity.

Note: 1 MLD = 1000 m^3/d

WHY MBR?


No or very little disinfection required
Low power consumption
Easy membrane replacement
High effluent quality
High automation
Low construction area
Easy for capacity upgrade
Advantages

WHY MBR?

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DISADVANTAGES

- Pretreatment is required before membrane tanks
- Strict operating regime
- Higher cost compared to traditional technology
- Membrane fouling occurs and cleaning is strictly required

FOULING AND CLEANING

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FOULING PHENOMENON

- Membrane fouling is caused by physicochemical interactions between foulants and membrane material.
- These foulants can be suspended particulates (microorganisms and cell debris), colloids, or solutes in the MLSS.

FOULING AND CLEANING

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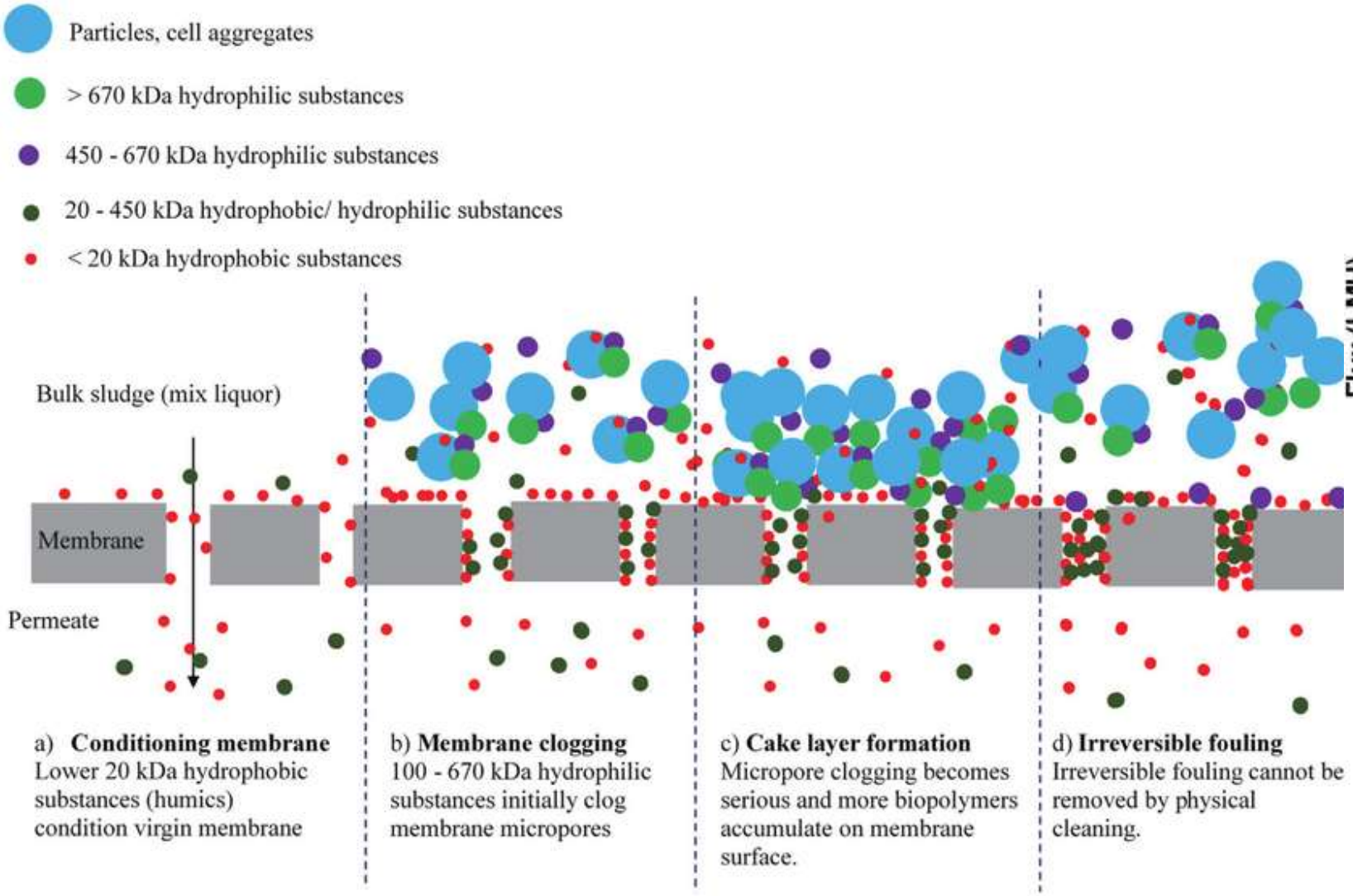
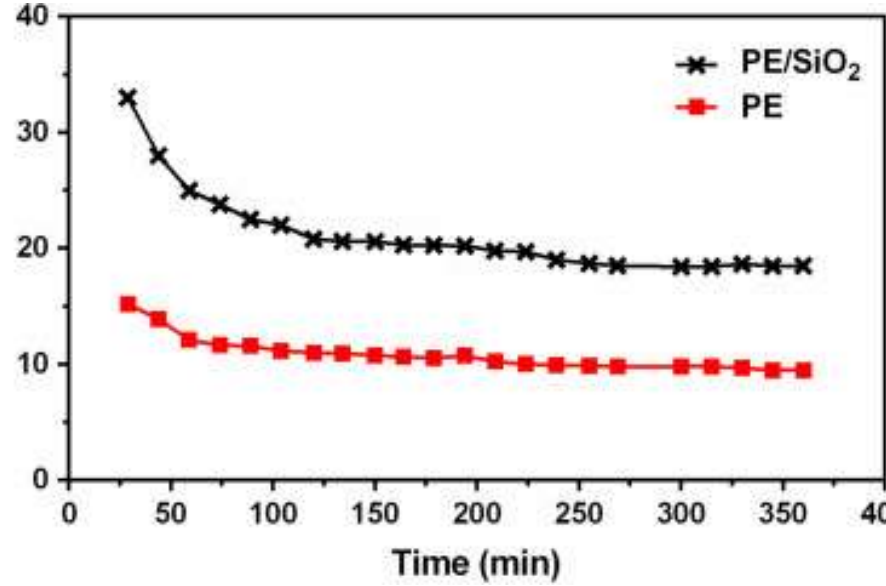
FOULING PHENOMENON





FOULING AND CLEANING

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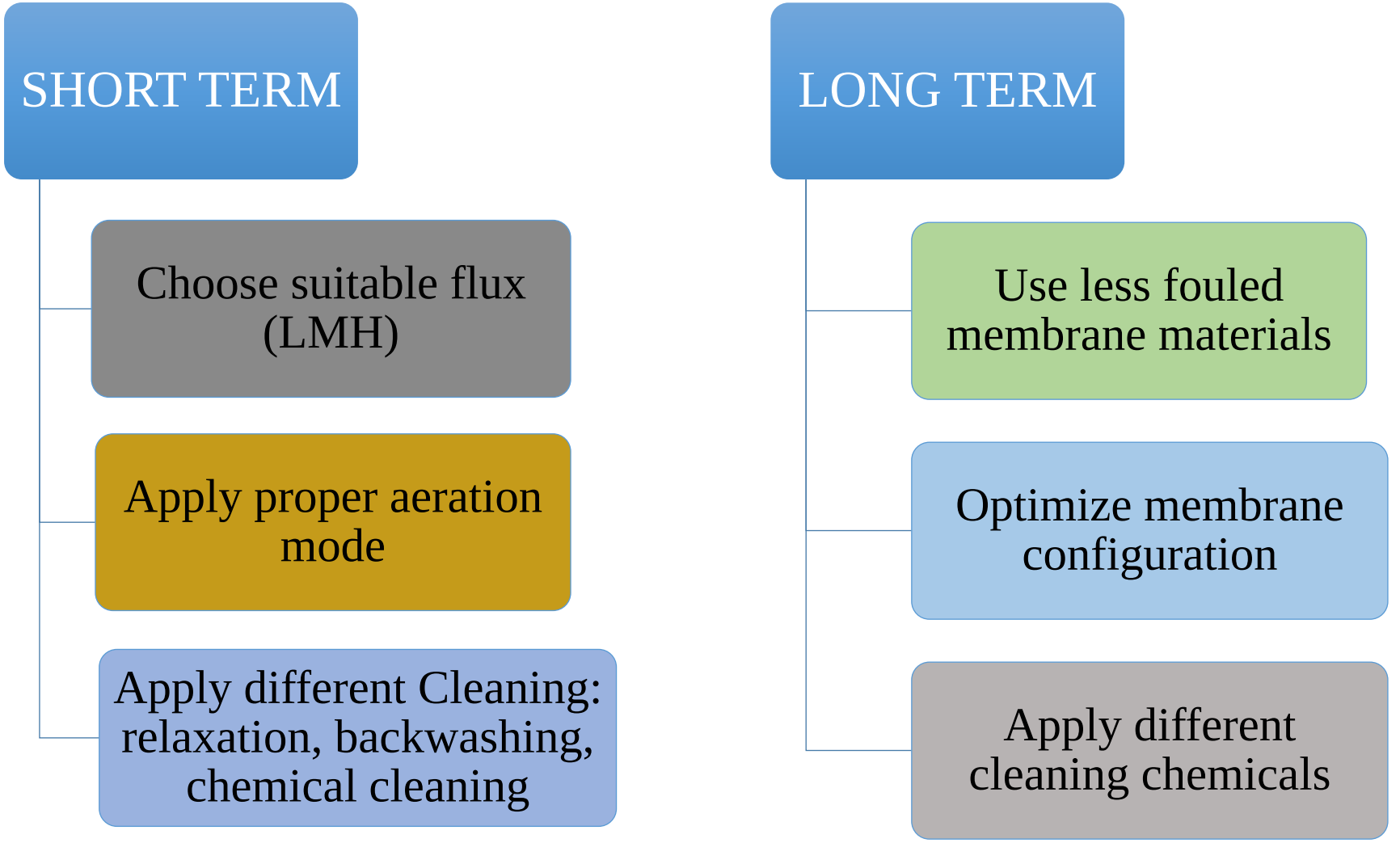
FOULING MITIGATION METHODS



FOULING AND CLEANING

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MEMBRANE CLEANING

- Clean-in-place (CIP) vs Clean-out-of-place
- Physical cleaning (by water) vs Chemical cleaning
- Chemicals: NaOCl and acids
- Maintenance cleaning vs Recovery cleaning

FOULING AND CLEANING

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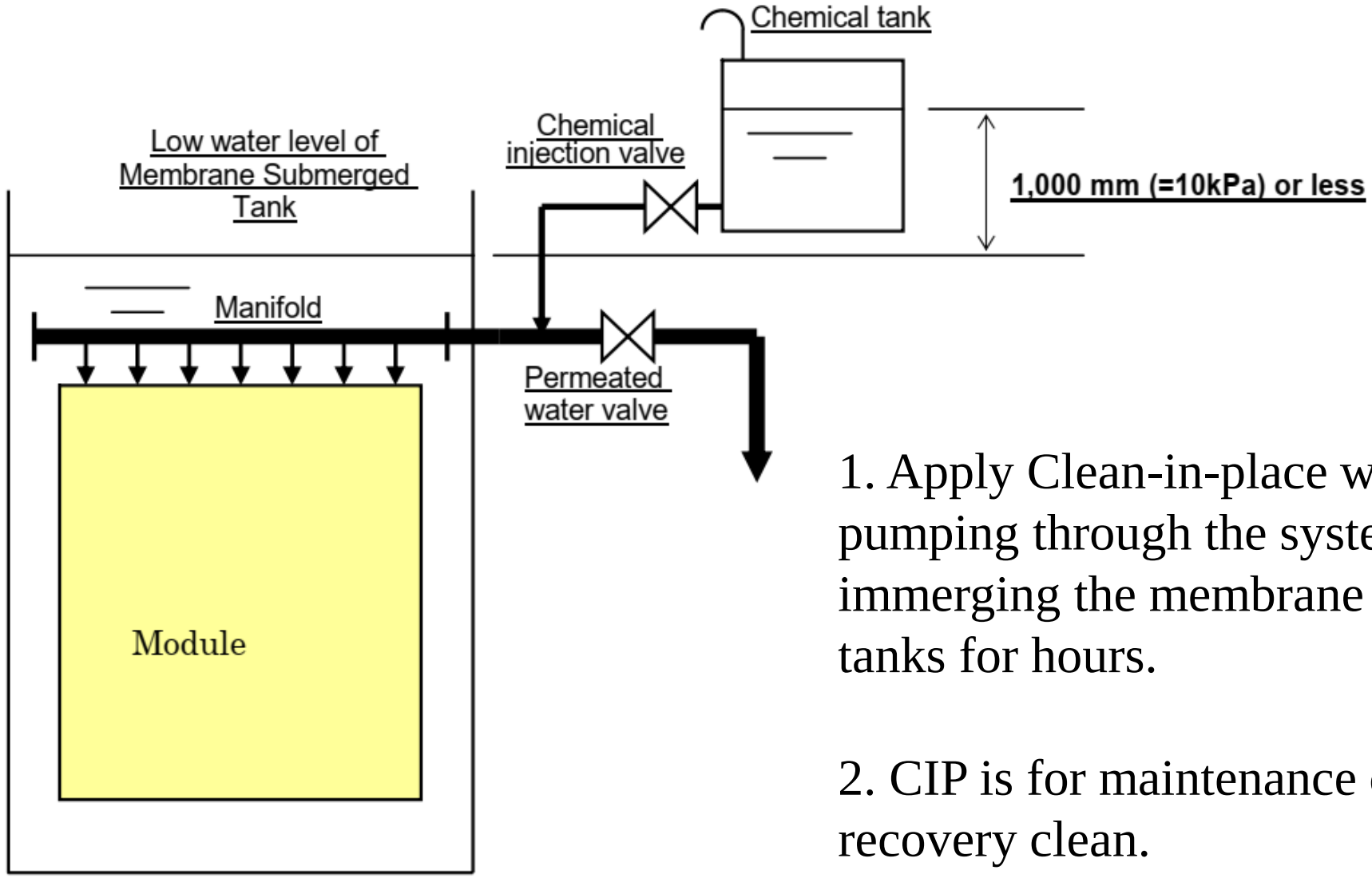
MEMBRANE CLEANING



1. Apply Clean-in-place with chemical solution pumping through the system or Clean-out-of-place by immerging the membrane modules in a chemical tanks for hours.

2. CIP is for maintenance clean while COP is used for recovery clean.

WW TREATMENT PROCESS USING MBR

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Design principles:

1. Evaluate influent water quality, effluent water quality requirements, main parameters such as: plant capacity, organic and nutrient loading rate
2. Evaluate requirements for preliminary treatment works
3. Select the number of filter membranes (number of units, modules) according to the required capacity and the type of membrane provided, membrane configuration (refers to the geometry of the membrane: hollow fiber, flat sheet, or tubular) as well as the direction in which the water flows through it (in-to-out or out-to-in); or submerged vs side stream
4. Run a pilot test to determine working parameters

MBR CONSIDERATIONS

Membrane operation parameters:

TMP of MF: 0.1 – 2 bar

TMP of UF: 2- 10 bar

Flux of MF: 40 – 90 LMH

Flux of UF: 10 - 40 LMH

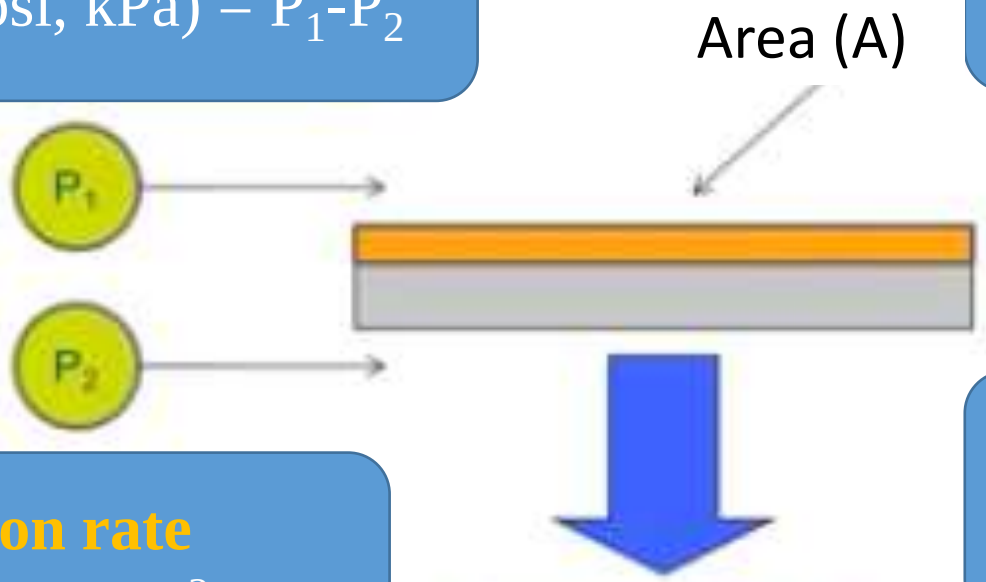
Transmembrane pressure

TMP (bar, psi, kPa) = P_1-P_2

Flux

Flow per unit area per unit time

L/m^2/h (LMH), gal/ft^2/d (GFD), m/d



Aeration rate

Air flowrate/m^2

Permeability

Flux per unit TMP (LMH/bar, GFD/psi)

Aeration rate: 0.2 - 0.5 L/min.m^2

MBR CONSIDERATIONS

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MBR system operation parameters:

Parameters	MBR
Hydraulic retention time, HRT (h)	4 - 20
Sludge retention time, SRT (days)	>15 days
MLSS (mg/L)	8000 - 25000
Sludge generation	Less
Secondary Clarifier	No
Filtration/Backwash (min)	10/0.5
Aeration mode	10-30s ON/10s OFF

APPLICATIONS OF MBR

Domestic Wastewater

Applicable to domestic wastewater with low to high organic matter and nutrient content

Industrial Wastewaters

Applicable to industrial wastewater with high organic matter and nutrient content

- Leachate WW
- Food industry WW
- Other high OM industry WW

TYPICAL MBR COMPACT

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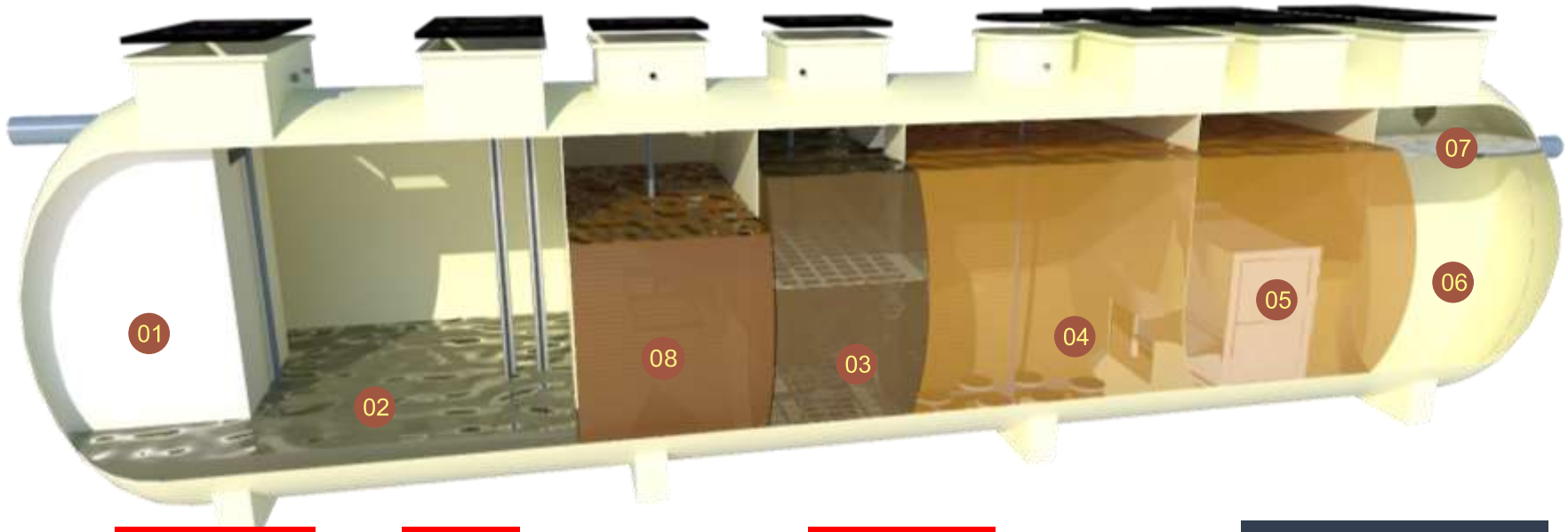
MBR Johkasou – For Small capacity
Model: FS – H – xP
Capacity: >10 m^3/d



01. Grit chamer
02. Equalization tank
03. Anoxic tank
04. Oxic tank
05. Membrane tank
06. Disinfection
07. Sludge discharge

Treatment process

Influent
BOD = 450 mg/L
TN = 100 mg/L
SS = 100 mg/L

Grit chamber → Equal. tank → Anoxic tank → Oxic tank → Membrane tank → Disinfection → Effluent

Effluent
BOD < 5 mg/L
TN < 5 mg/L
SS < 1 ml/L

Sludge
Supernatant
Methanol
PAC
Return
NaOCl

Blowers

MBR CONSIDERATION DURING OPERATION

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- Maintain MLSS concentration within the required range of 5000 – 12000mg/l (lowest is 3000mg/L and maximum is 15000mg/L). Higher concentrations of MLSS can result in increased viscosity while reducing membrane cleaning and causing sludge adhesion between membrane pores. The result is an increase in the TMP value (transmembrane pressure), clogging the membrane and leading to membrane destruction.

- When the pressure on the membrane surface exceeds 20kPa (0.2 bar) for MF or 1 bar for UF, chemical cleaning is performed.

MBR CONSIDERATION DURING OPERATION

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- Maintain the amount of aeration to wash the membrane within the standard range of 100 - 150 $Nm^3/m^2.h$. If this value reaches 200 $Nm^3/m^2.h$ it can cause membrane damage.
- Chemicals including NaOCl, citric acid, oxalic acid, HCl acid, and H_2SO_4, are used to clean the membrane.
- Membrane units must be stored and transported under temperature conditions ranging from 0 – 40oC
- and in dry conditions.
- Do not use objects such as high-pressure washers to wash the membrane to avoid damaging the membrane.
- Do not use membranes to treat wastewater containing volatile organic compounds. Do not use chemicals that can stretch the membrane fibers, or destroy or decompose the membrane fibers.

MBR APPLICATION CASE 1

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Wastewater treatment plant in Pooler, Bang Georgia, Mỹ

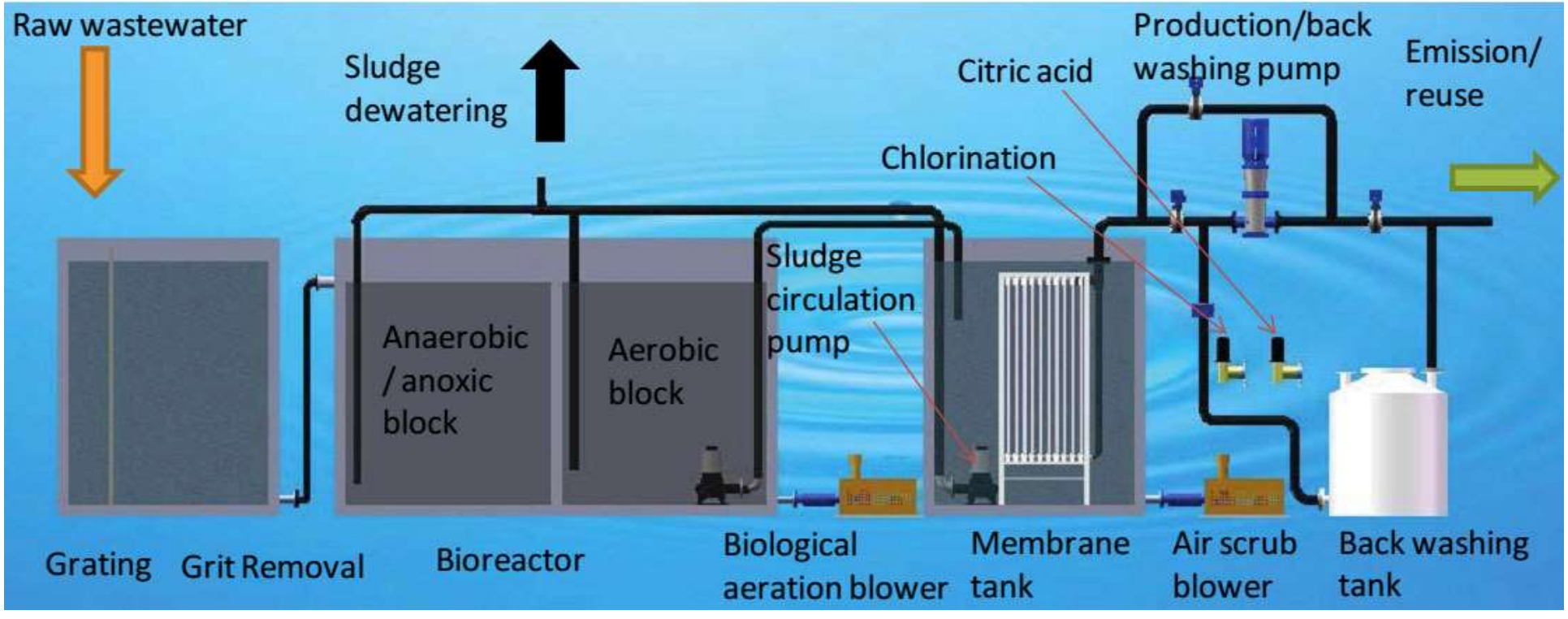
Capacity: 9500 m^3/d, using UF-MBR from SUEZ company

Old treatment process:

Bar screen + Grit tank + Biological ponds

New treatment process:

Bar screen + Grit tank + AO-MBR + Disinfection



MBR APPLICATION CASE 1

FUDESO® TECHNOLOGY OF FUTURE

Wastewater treatment plant in Pooler, Bang Georgia, Mỹ

MBR: 4 train of SUEZ membranes), each train has 3 cassettes, each cassette has 32 modules.
02 blowers
Aeration mode: 10s on – 10s off (sometimes10s on, 30s off)

Typical Effluent for the Pooler WWTP			
Parameter	**Influent**	**Treated Effluent**	**Current Limit**
BOD (mg/L)	210	< 5	4
TSS (mg/L)	210	< 2	10
NH3-N (mg/L)	30	< 0.7	1.6
Turbidity (NTU)	NA	< 3	NA
Fecal Coliform (CFU/100 mL)	NA	< 23[1]	NA

MBR APPLICATION CASE 2

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Wastewater treatment plant Traverse city, Mỹ

Capacity: 8.5 MGD (33.000 m3/d)

Old treatment process:

Bar screen + Grit chamber + Clarifier 1+ Aeroten + Clarifier 2 + Disinfection

New treatment process:

Son Bar screen + Grit chamber + Clarifier 1+ MBR + Disinfection

MBR APPLICATION CASE 2

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Wastewater treatment plant Traverse city, USA

- MLSS < 10.000 mg/L
- SRT: 14 days
- Flux: 15 LMH
- Weekly maintenance clean with NaOCl or Citric acid
- Annual recovery clean with NaOCl and Citric acid

- Capital cost: $31 mil.
- Annual Operation Cost:
  - Electricity: - $ 0.22 / 1,000 gal
  - Ferric chloride - 55,000 gal/year of 40%
  - Sodium hypochlorite & Citric acid - $23,200 /year
  - $1.34/1,000 gal for O&M

MBR APPLICATION CASE 3

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Wastewater treatment in Hoa Lu ancient town, Ninh Binh province.
Capacity: 150 m3/day

MBR APPLICATION CASE 3

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Wastewater treatment in Hoa Lu ancient town, Ninh Binh province.
Capacity: 150 m3/day

- MLSS < 7.000 mg/L
- SRT: 10 ngày
- Weekly maintenance clean with NaOCl or Citric acid
- Annual recovery clean with NaOCl and Citric acid

- Capital cost : $167,000
- Annual Operation Cost:
  - Electricity - $ 4,120/year
  - PAC - $ 450/năm.
  - Sodium hypochlorite & Citric acid - $7,360 /year
  - $5,000/year for O&M

  This cost is for full capacity of 150m3/d

MBR APPLICATION CASE 4

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Wastewater treatment in Tam Chuc pagoda, Ninh Binh province.
Capacity: 320 m3/day

MBR APPLICATION CASE 3

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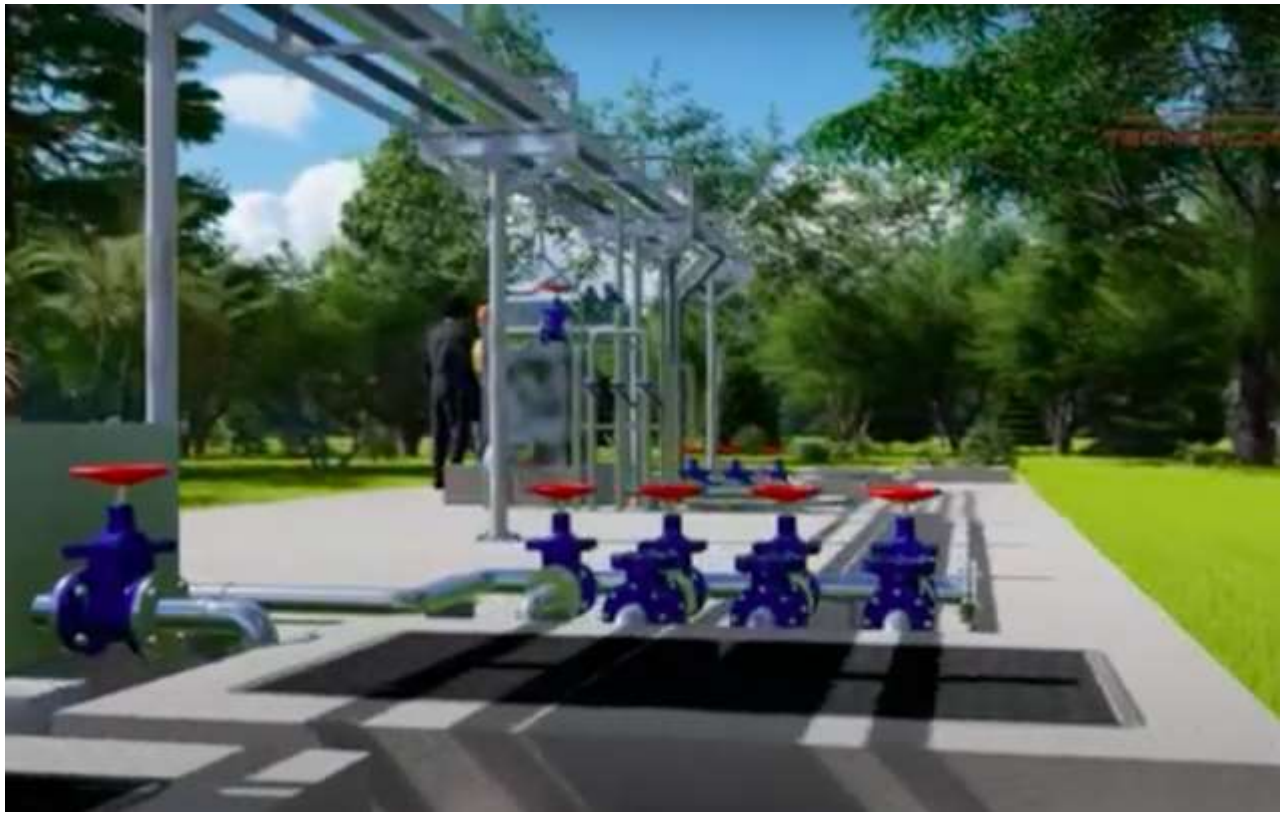
Wastewater treatment in Tam Chuc pagoda, Ninh Binh province.

Capacity: 320 m3/day



- MLSS < 7.000 mg/L
- SRT: 10 ngày
- Design Flow: 320 m3/d
- Weekly maintenance clean with NaOCl or Citric acid
- Annual recovery clean with NaOCl and Citric acid
- Capital cost: $250,000
- Annual Operation Cost:
  - Electricity - $ 8,500/year
  - PAC- $ 900/year
  - Sodium hypochlorite & Citric acid - $ 15,000 /year
  - $10,000 for O&M

  This cost is for full capacity of 320m3/d

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THANK YOU AND QUESTION?

Any further question: email to huyendtt@huce.edu.vn