Membrane Bioreactor Technology

Basic engineering design

Technical presentation for WWE Sdn Bhd

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Presentation outline

- Objectives
- Which membrane systems?
- Configurations
- Aeration techniques
- Activated sludge microbial populations
- Biomass separation

Objectives?

- Organic removal
- Organic removal and nitrification
- Organic, nitrogen removal & water recycling
- Organic and nutrient removal & water recycling
- Persistent organic removal & water recycling
- High strength waste management
- Cleaner production

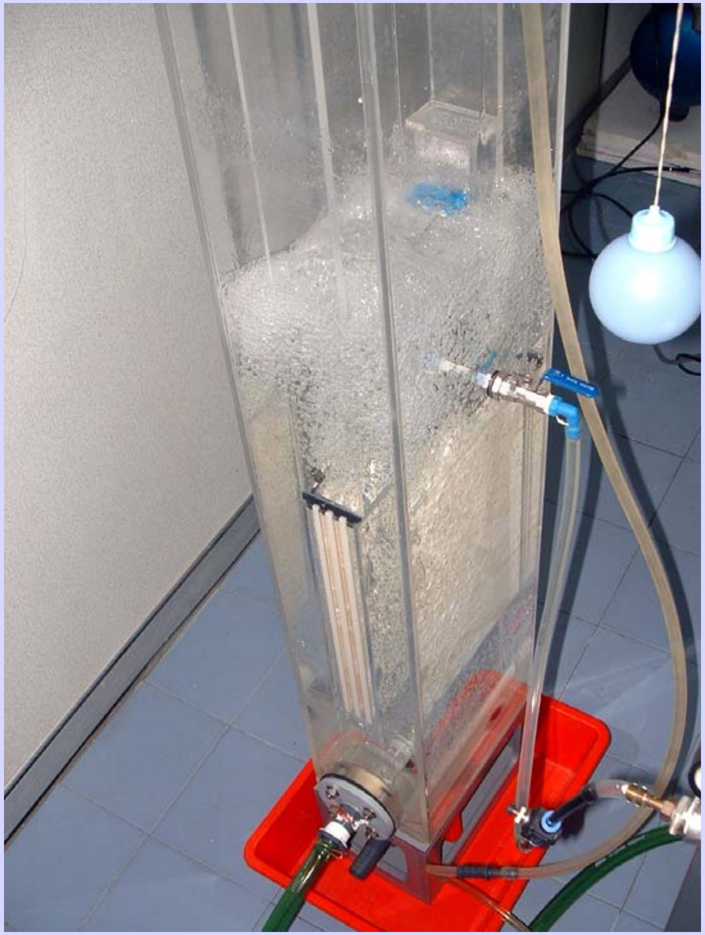
Objectives & systems

Objectives	MBR	Conventional
1	Not recommended	WSP, CAS, RBC etc
2	Not recommended	CAS, EA, RBC etc
3	Recommended	AS + RO
4	Recommended	AS + RO
5	Recommended (Hybrid MBR)	AS + RO + GAC
6	Recommended (Hybrid MBR)	Hybrid
7	Recommended (Hybrid MBR)	Hybrid

1=Organic removal, 2=Organic removal and nitrification, 3=Organic, nitrogen removal & water recycling 4=Organic and nutrient removal & water recycling, 5=Persistent organic removal & water recycling, 6=High strength waste, 7 =Cleaner production

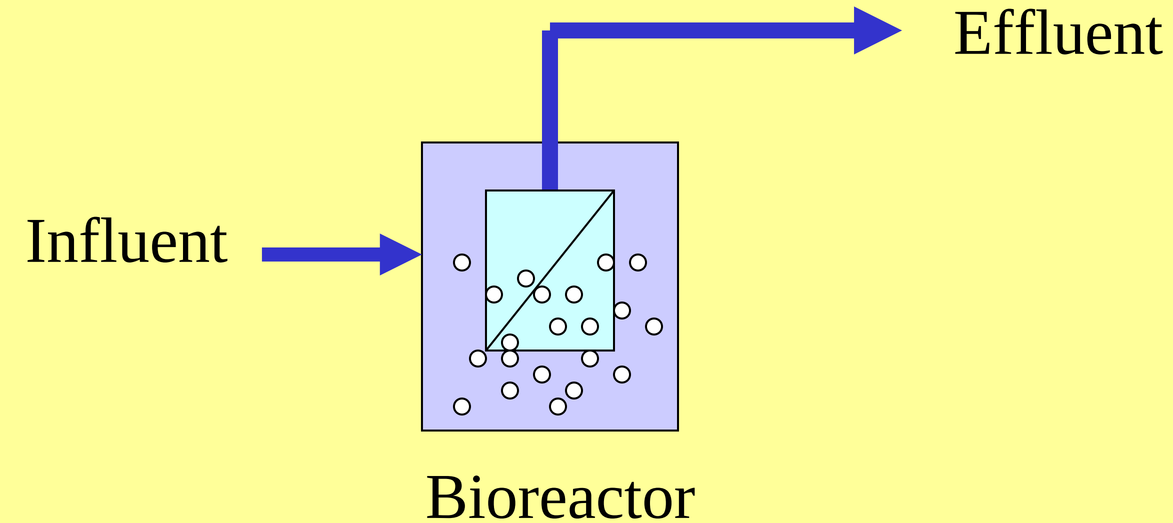
MBR processes

- Membrane separation bioreactors
- Membrane aeration bioreactors
- Extractive membrane bioreactors



MBR processes

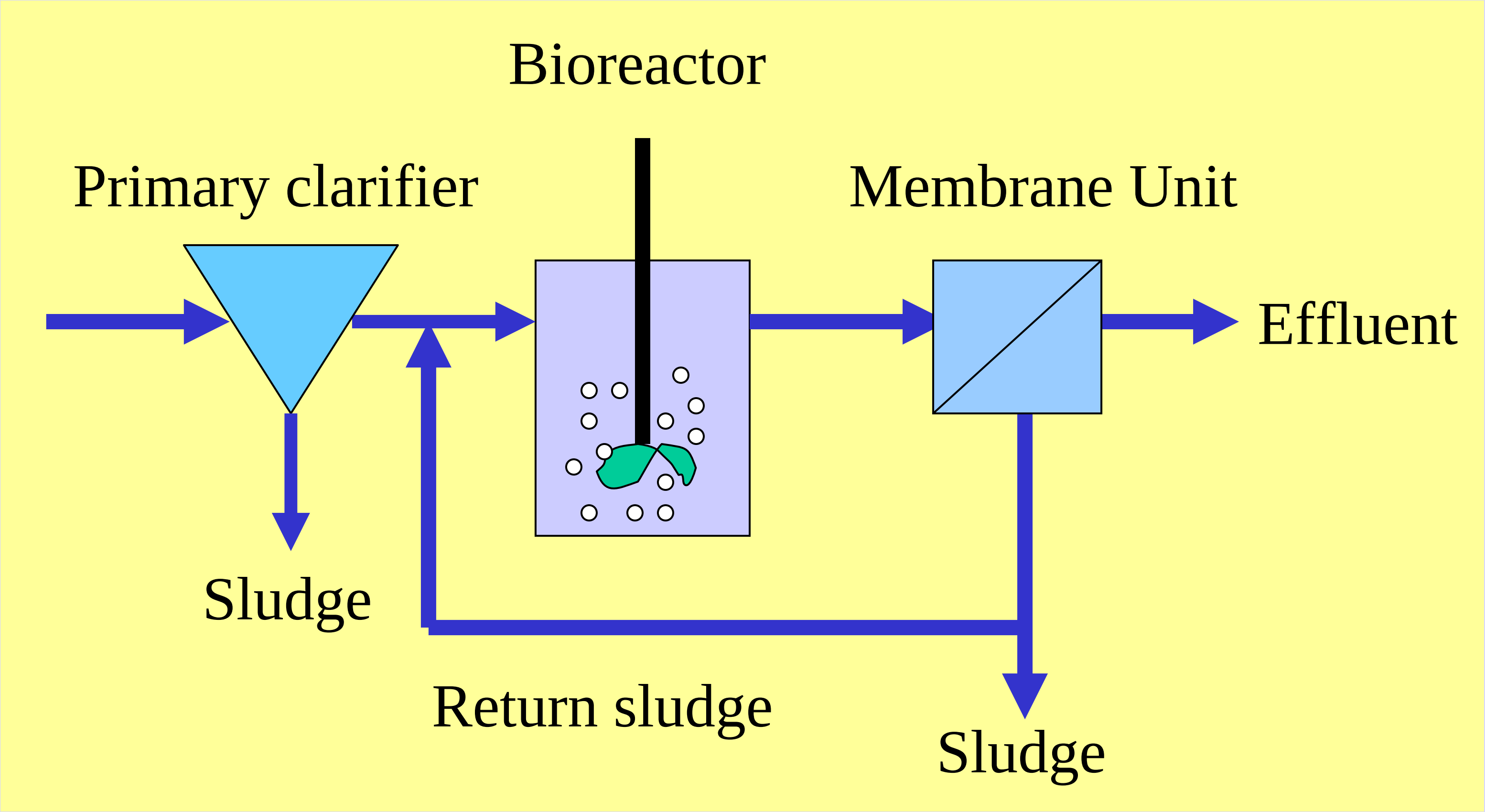
Membrane separation bioreactors – Submerged



Activated Sludge-Based Membrane System

MBR processes

Membrane separation bioreactors – Side-stream



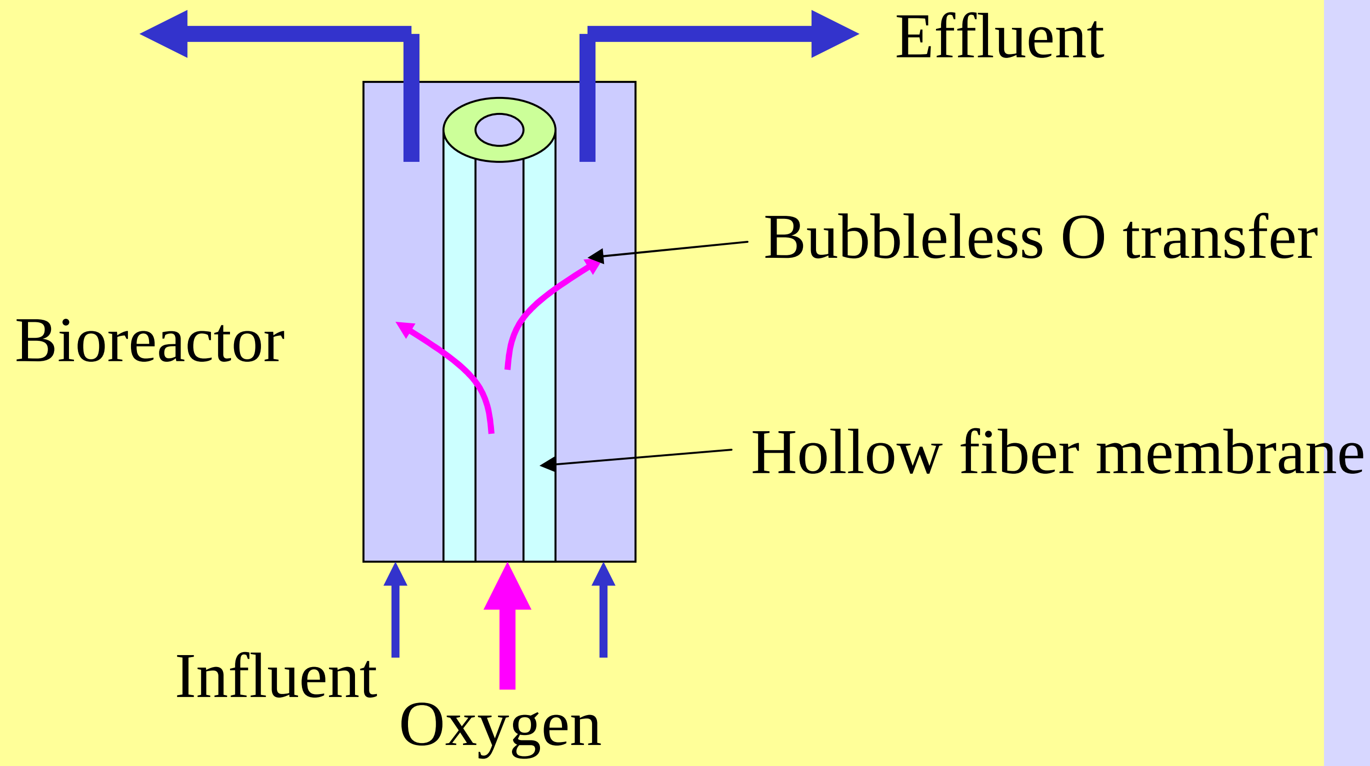
MBR Technology

Membrane separation bioreactors

Advantages	Disadvantages
-Small footprint	-Aeration limitation
-Complete solid removal	-Membrane fouling
-Effluent disinfection	-Membrane costs
-Removal of organic, nutrient & solid	
-High loading rate capability	
-Low/zero sludge production	
-Rapid start up	
-Sludge bulking not a problem	
-Modular/retrofit	

MBR processes

Membrane aeration bioreactors



Gas Separation-Based Membrane System

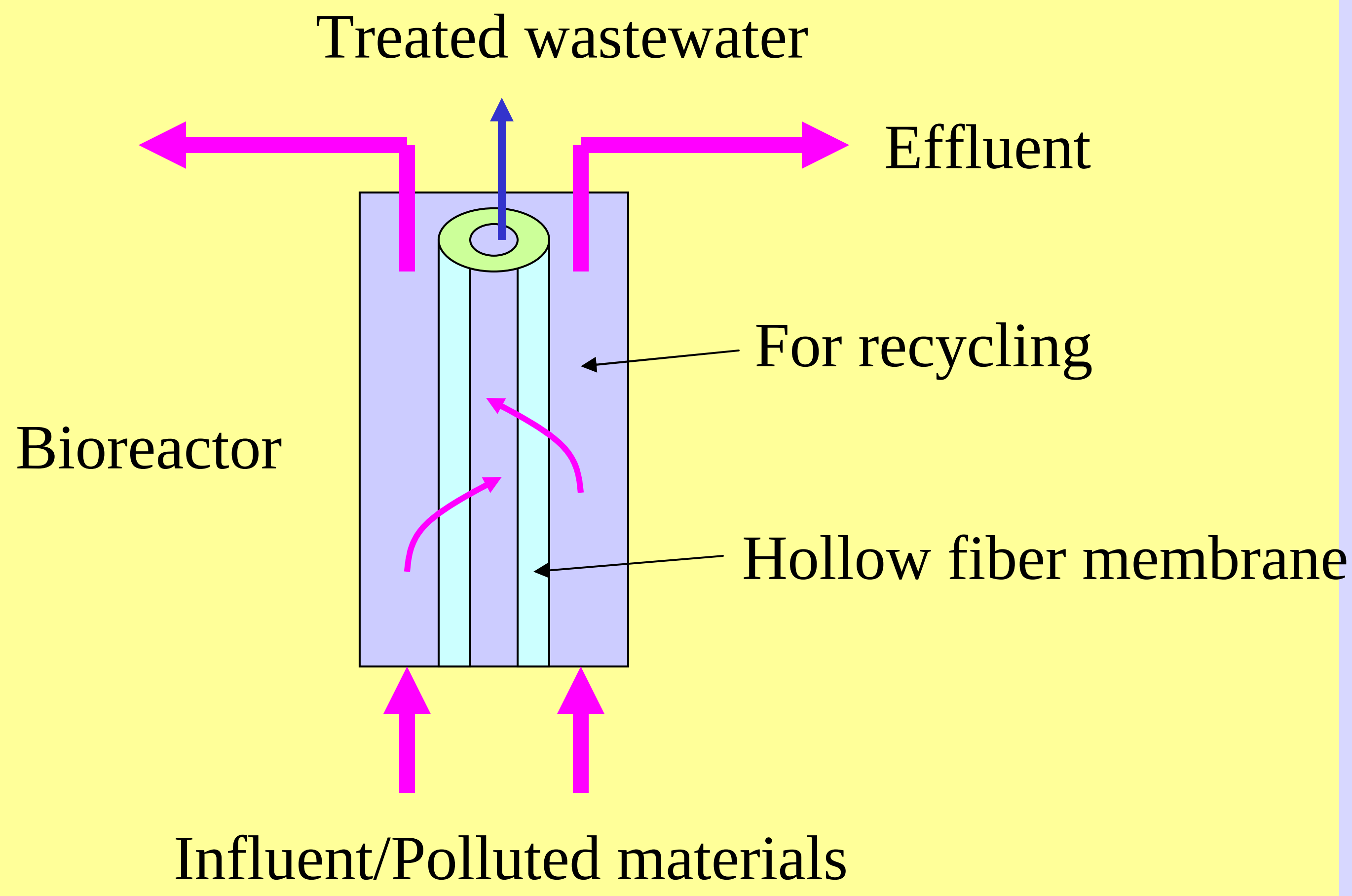
MBR Technology

Membrane aeration bioreactors

Advantages	Disadvantages
-High oxygen utilization	-Membrane fouling
-Highly efficient energy utilization	-High capital cost
-Small foot print	-Unproven at full scale
-Feed-forward control of O demand	-Process complexity
-Modular/retrofit	

MBR processes

Membrane extractive bioreactors



Gas Separation-Based Membrane System

MBR Technology

Extractive membrane bioreactors

Advantages	Disadvantages
-Treatment of toxic industrial effluents	-High capital cost
-Small effluents	-Process complexity
-Modular/retrofit	-Unproven at full scale
-Isolation of bacteria from wastewater	

Performance comparison between activated sludge and MBR (Cicek et al., 1999)

Parameters	Activated sludge	MBR
Sludge age (d)	20	30
COD removal (%)	94.5	99
DOC removal (%)	92.7	97
TSS removal (%)	60.9	99.9
A-N removal	98.9	99.2
Total P removal (%)	88.5	96.6
Slude production (kg VSS/COD.d)	0.22	0.27
Mean floc size (μm)	20	3.5

Design criteria MBR

Parameters	Design values
Loading rates (for >90% organic removal)	1.2 to 3.2 kg COD/m^3.d 0.05 to 0.66 kg BOD/m^3.d
Loading rates for complete nitrification	0.05 to 0.66 kg BOD/m^3.d Sludge age 10 to 50 d
Loading rate for complete nitrogen removal	4 kg NH_4-N/m^3.d 5 kg NO_3-N/m^3.d
MLSS	10,000 to 20,000 mg/l
Flux	5 to 300 L/m^2.h
Specific flux	20 to 200 L/ m^2 h bar
Design flux (Kubota, ϕ of 0.4 μm)	0.5 m^3/m^2.d (specific flux 125-175 L/ m^2 h bar)

Aerobic MBR

Examples of design criteria

Wastewater	Type	V (m^3)	HRT (h)	θ (d)	Organic load (kg/m^3d)	MLSS (kg)	Sludge yield (d)	Air (m^3/h)
Raw sewage (Ueda& Hata, 1999)	HF/S/ PE	3.12	13.4	72	0.245	12.9	-	18
Municipal (Cote et al., 1997)	HF/S	1	4.8	-	2.3	26	0.2	0.5-1.5
Raw sewage (Ueda et al, 1999)	HF/S	21.4	13	120	0.315	12	-	42

Aerobic MBR configurations

Examples of specific fluxes

Configurations	Specific fluxes	References
Submerged HF	50 to 65 $L/m^2.h.bar$	Gunder & Krauth, 1998
Flat plate	115 $L/m^2.h.bar$	Gunder & Krauth, 1998
Tubular side-stream	40 to 60 $L/m^2.h.bar$	Le Clech et al., 1999

MBR technology

Materials and pore size

	Pore size	Materials
UF and MF submerged	0.02 to 0.5 μm	Polyethylene, polypropylene, polysulphone etc
UF and MF Side-stream	0.02 to 0.5 μm	Ceramics (MF), polyethylene, polypropylene, polysulphone etc
NF submerged	<0.02 μm	Polyethylene, polypropylene, polysulphone etc

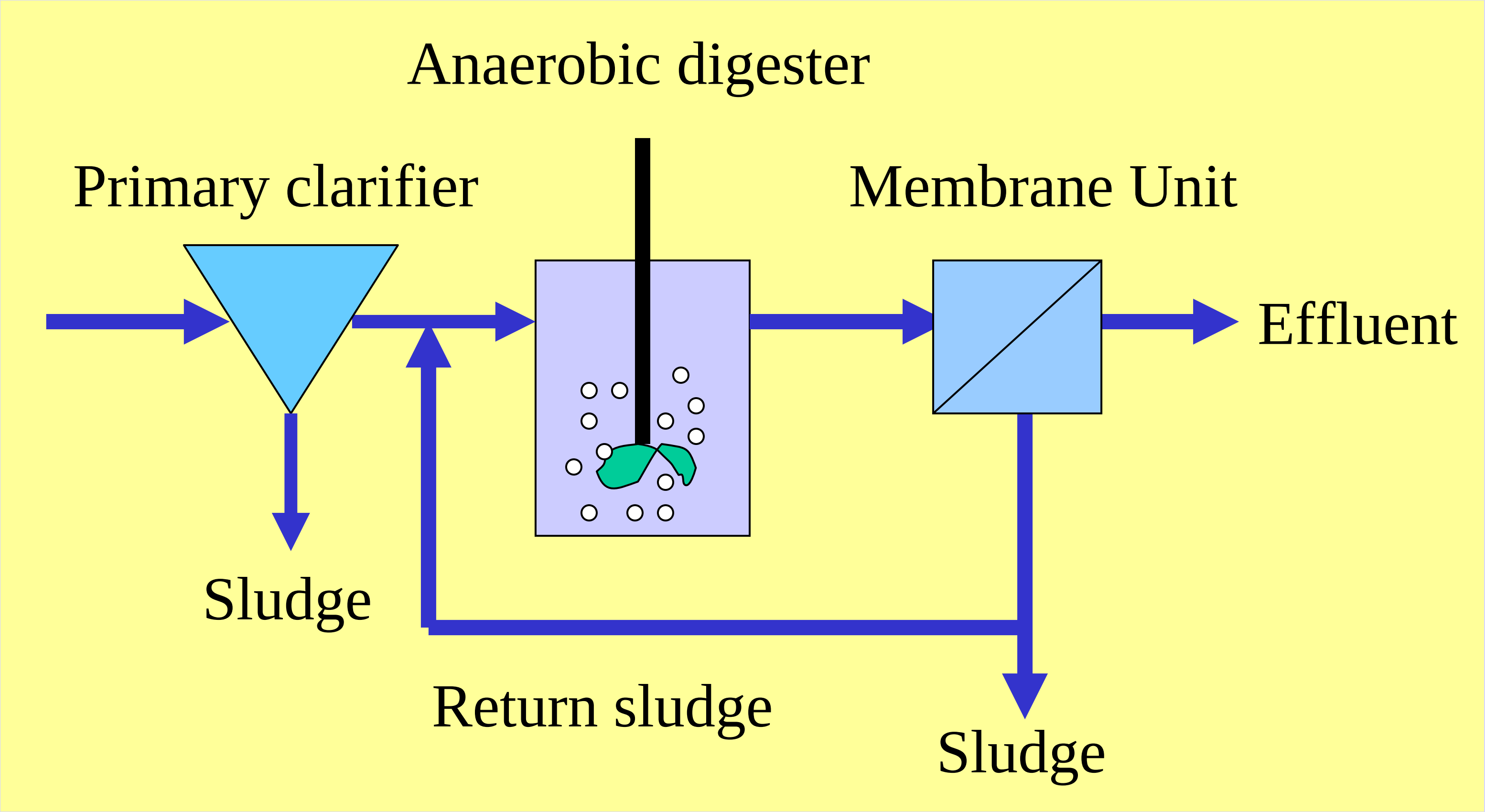
Aerobic MBR: Energy consumption

Pumping influent, recycling retente, permeate suction & aeration

	Energy requirement	References
MF submerged	0.2 to 0.4 kW.h/m^3	Cote et al., 1998
MF side-stream	2 to 10 kW.h/m^3	Cote et al., 1998
MF hollow fibre submerged	0.3 kW.h/m^3 (0.28 for aeration)	Cote et al., 1997

Anaerobic MBR technology

Membrane separation bioreactors – Side-stream



Anaerobic MBR

Loading rates

Parameters	Values	References
Side-stream MBR -Loading rates (acidogenic)	54 kg COD/m^3.d	Anderson et al., 1986
Side-stream MBR - Loading rates (methanogenic)	12.2 kg COD/m^3.d	Anderson et al., 1986
Submerged MBR- Loading rates	15 kg COD/m^3.d	Li et al, 1985; Kayawake et al., 1991
HRT	67 h - POME 124 h - maize waste	

Typical values for the design parameters for activated sludge processes …

Process	θ, d	F/M, lb BOD/ lb MLVSS.d	Volumetric loading, lb BOD / 10^3 ft^3.d	MLSS, mg/l	V/Q, h	Q_r/Q
Conventional plug flow	3-15	0.2-0.6	20-40	1000-3000	4-8	0.25-0.75
Complete mix	0.75-15	0.2-1.0	50-120	800-6500	3.5	0.25-1.0
Step feed	3-15	0.2-0.5	40-60	1500-3500	3-5	0.25-0.75
Single-stage nitrification	8-12	0.10-0.2	5-20	1500-3500	6-15	0.5-1.5
Separate-stage nitrification	15-100	0.05-0.2	3-9	1500-3500	3-6	0.5-2

… Typical values for the design parameters for activated sludge processes

Process	θ, d	F/M, lb BOD/ lb MLVSS.d	Volumetric loading, lb BOD / 10^3 ft^3.d	MLSS, mg/l	V/Q, h	Q_r/Q
Contact stabilization	5-15	0.2-0.6	60-70	1000-3000	0.5-1	0.5-1.5
Extended aeration	20-40	0.04-0.1	5-15	2000-8000	18-36	0.5-1.5
Oxidation ditch	15-30	0.04-0.1	5-15	2000-8000	8-36	0.5-1.5
Intermittent decanted EA	12-25	0.04-0.08	5-15	2000-8000	20-40	NA
Sequencing batch reactor	10-30	0.04-0.1	5-15	2000-8000	12-50	NA

Design procedure for submerged MBR

Steps	V/Q, h	Q_r/Q
Wastewater characterization, and flow rate	0.5-1	0.5-1.5
Objectives?	18-36	0.5-1.5
Oxidation ditch	8-36	0.5-1.5
Intermittent decanted EA	20-40	NA
Sequencing batch reactor	12-50	NA