Membrane Fouling Studies in Suspended and Attached Growth Membrane Bioreactor Systems

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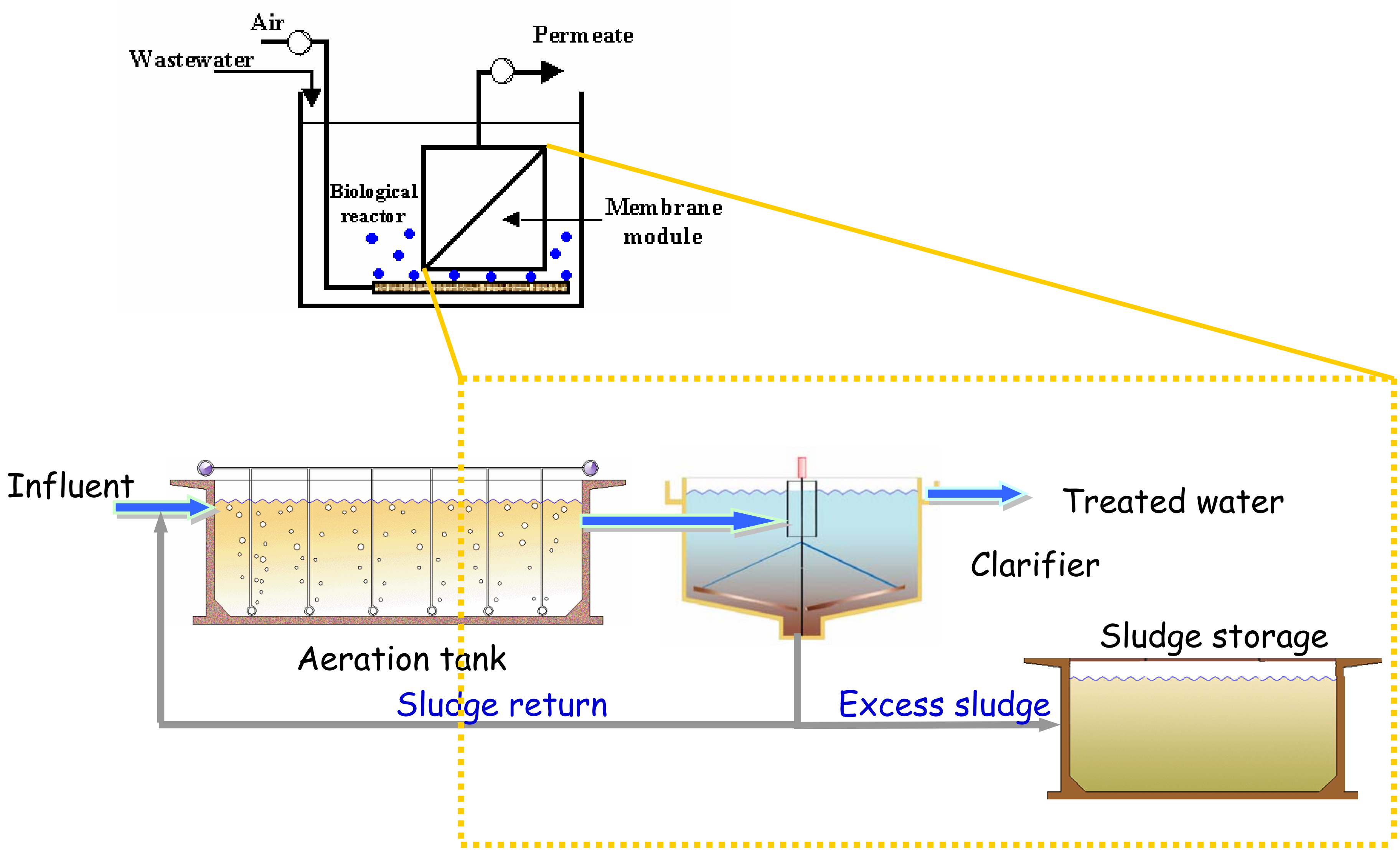
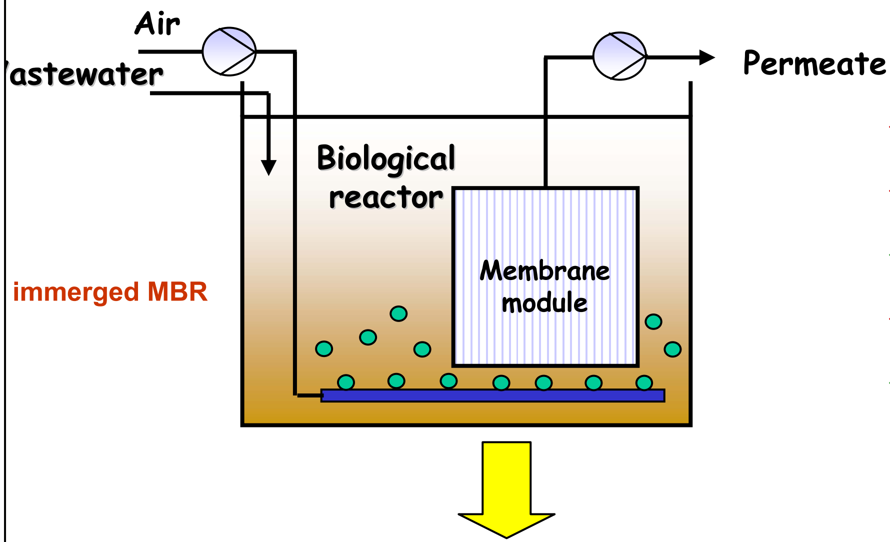
Membrane Bioreactor System



Advantages and disadvantages of membrane bioreactor

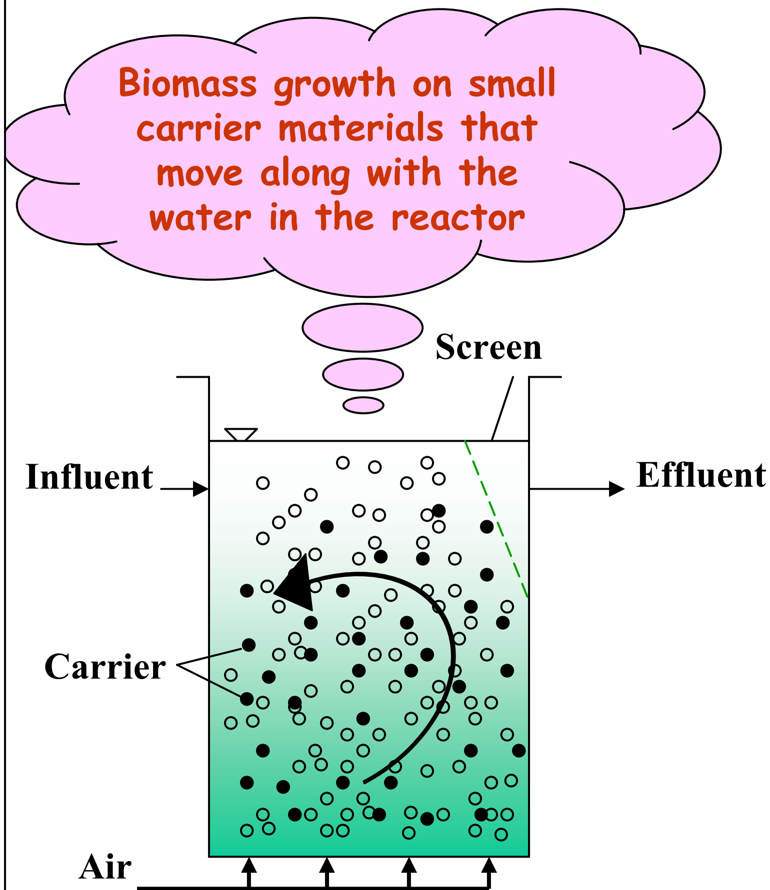


- High effluent quality
- Small size
- Flexible in the operation
- Low sludge production
- Removal of infectious pathogens

Limitation of MBR : *Fouling*

- A reduction of the membrane performance
- A decrease of flux
- An increase in filtration resistance
- Membrane cleaning requirement

Attached growth bioreactor



Attached growth reactor

Advantage for attached growth bioreactor

Better oxygen transfer

High organic removal ability

Relatively short HRT

Being more compact

(Tavares et al, 1994; Ødegaard et al,1994; Ødegaard 2000)

Objectives of the study

- To examine suitable test conditions and to select suitable media for attached growth reactor
- To investigate effects of operating conditions, such as HRT and MLSS on membrane performance, fouling characteristics, EPS production and sludge properties
- To compare membrane fouling behavior of attached and suspended growth MBRs

Scope of the study

- Synthetic wastewater with a constant COD value of 500 mg/L

- Five different types of media
  polyethylene bead (PB), polyethylene granule (PG), polyethylene sheet (PS), cylindrical polypropylene (CP) and polyethylene sponge (S)

- Effect of operating conditions;
  1. HRT was varied at 2, 4, 6 and 8 h.
  2. MLSS was altered at 6, 10 and 15 g/L.

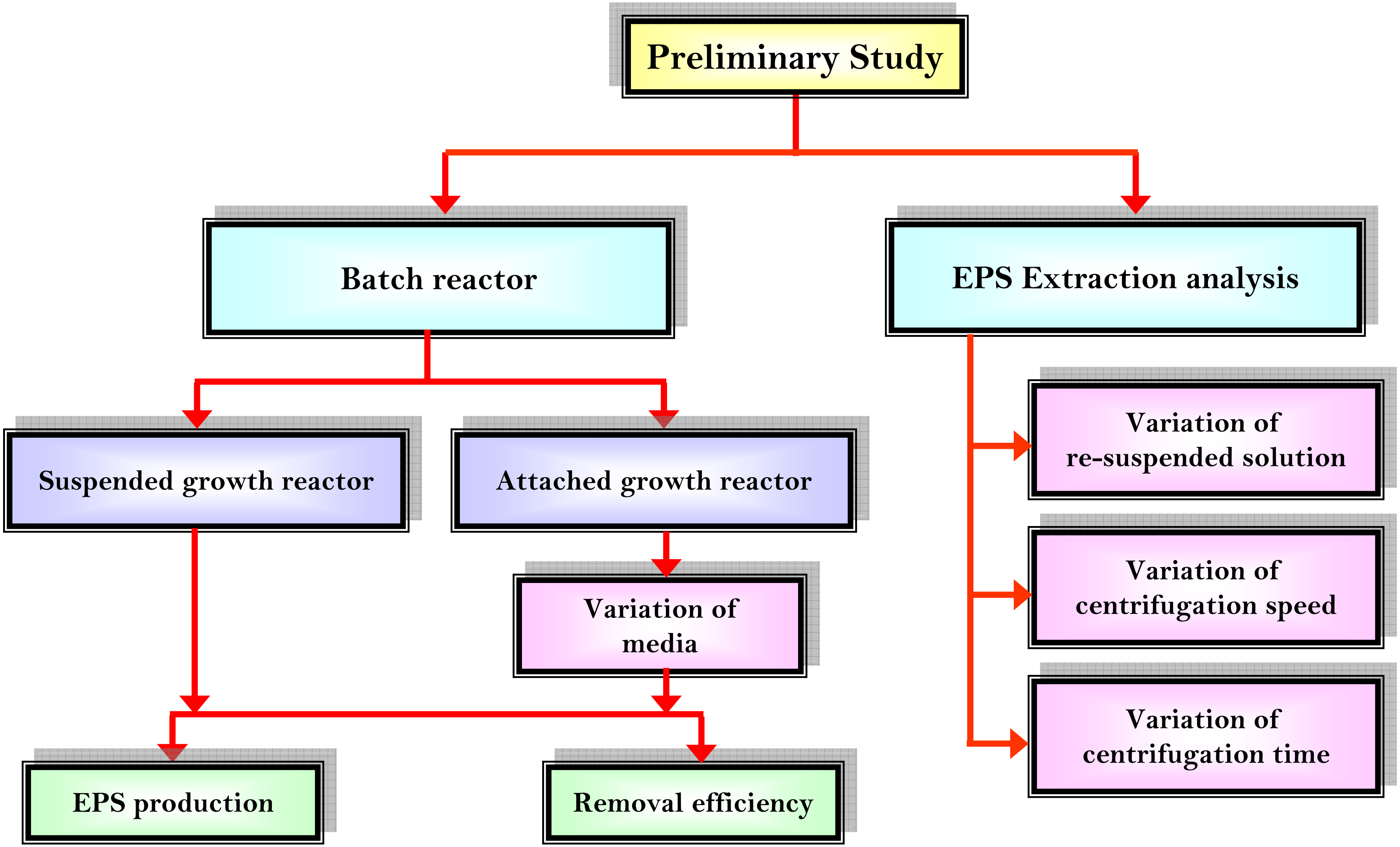
- Sludge characteristics, EPS production, fouling rate, cake resistance and microscope observation

- Removal efficiency of COD, and nitrogen compounds

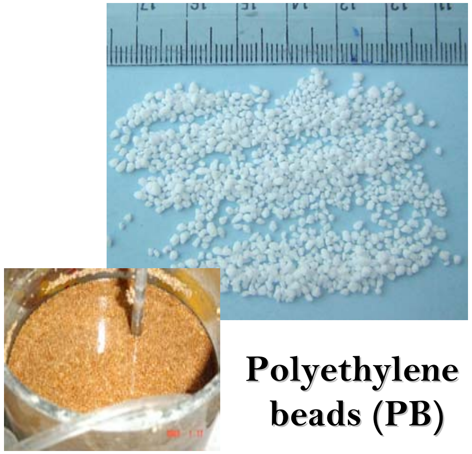
Preliminary study

- To examine suitable test conditions and to select suitable media for attached growth reactor

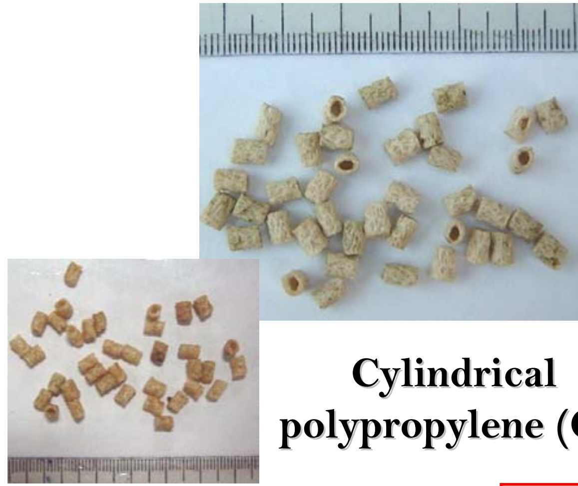
Research methodology



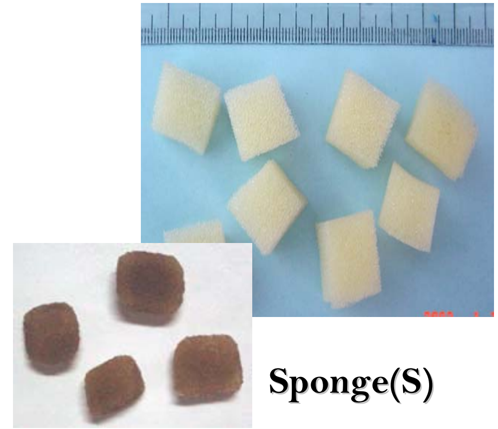
Media types



Polyethylene beads (PB)

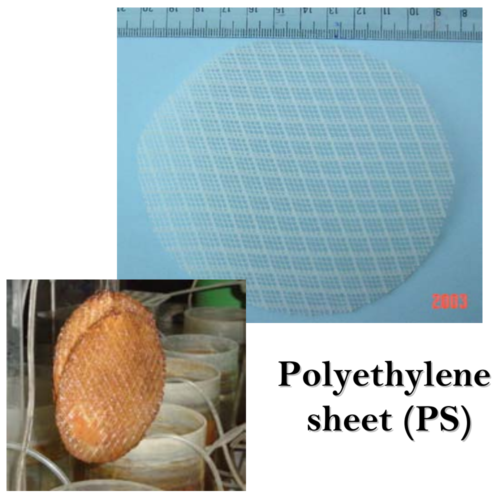


Cylindrical polypropylene (CP)



Sponge(S)

Polyethylene granule (PG)



Polyethylene sheet (PS)

Experimental set-up and operation

Conditions: pH 7-8 | DO 2-4 mg/L
COD 500 mg/L | HRT 6 h.
SRT 10 d. | MLSS 4000 mg/L
F/M 0.1 kgCOD/kgMLSS.d

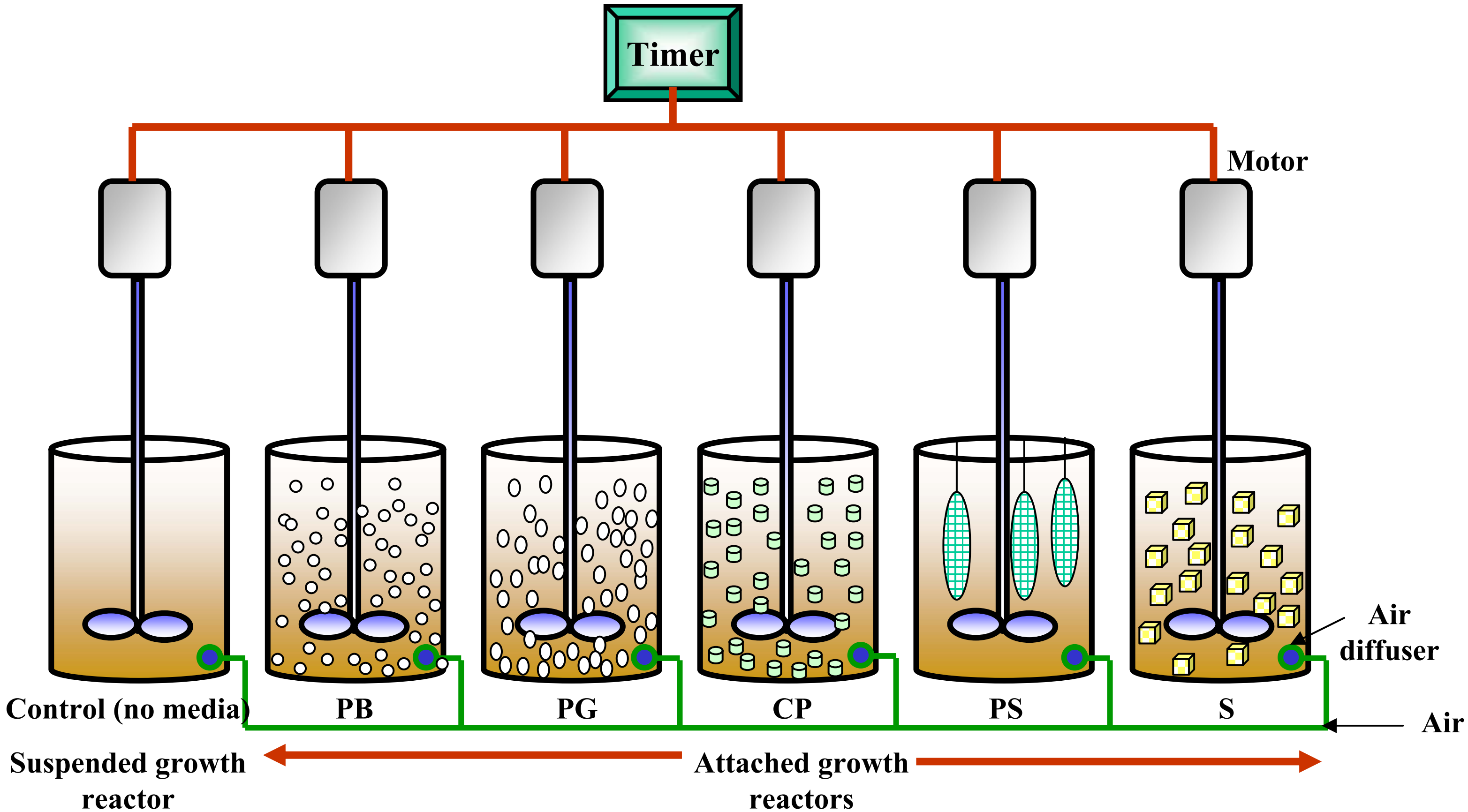


Table 4.1 Removal efficiency of COD and TKN in batch reactors

Batch reactor	System	Sampling point	COD		TKN	
			mg/L	% removal	mg/L	% removal
	-	Influent	460	-	30	-
Control (no media)	Suspended growth	Effluent	23	95	6	79
PB	Attached growth	Effluent	23	95	4	88
PG	Attached growth	Effluent	22	95	3	90
PS	Attached growth	Effluent	21	95	4	86
CP	Attached growth	Effluent	22	95	4	86
S	Attached growth	Effluent	25	94	5	83

A. Selection of Media Type for Attached Growth Reactor

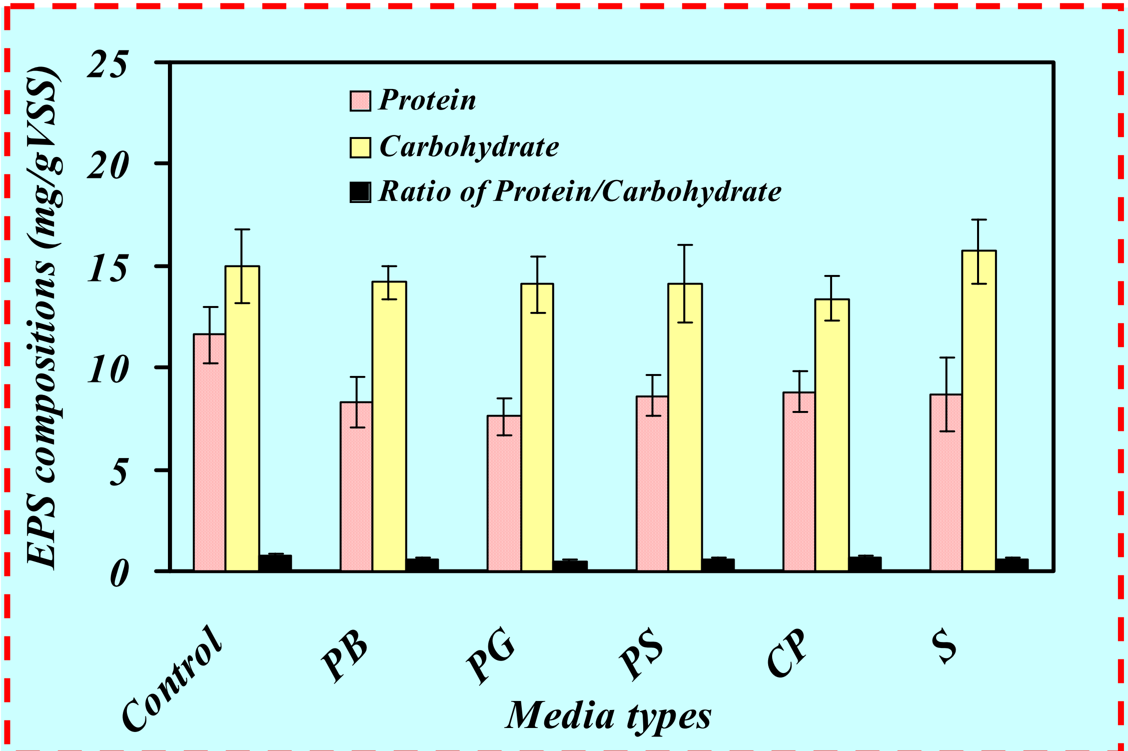


Figure 4.2 EPS compositions in different media types

A. Selection of Media Type for an Attached Growth Reactor

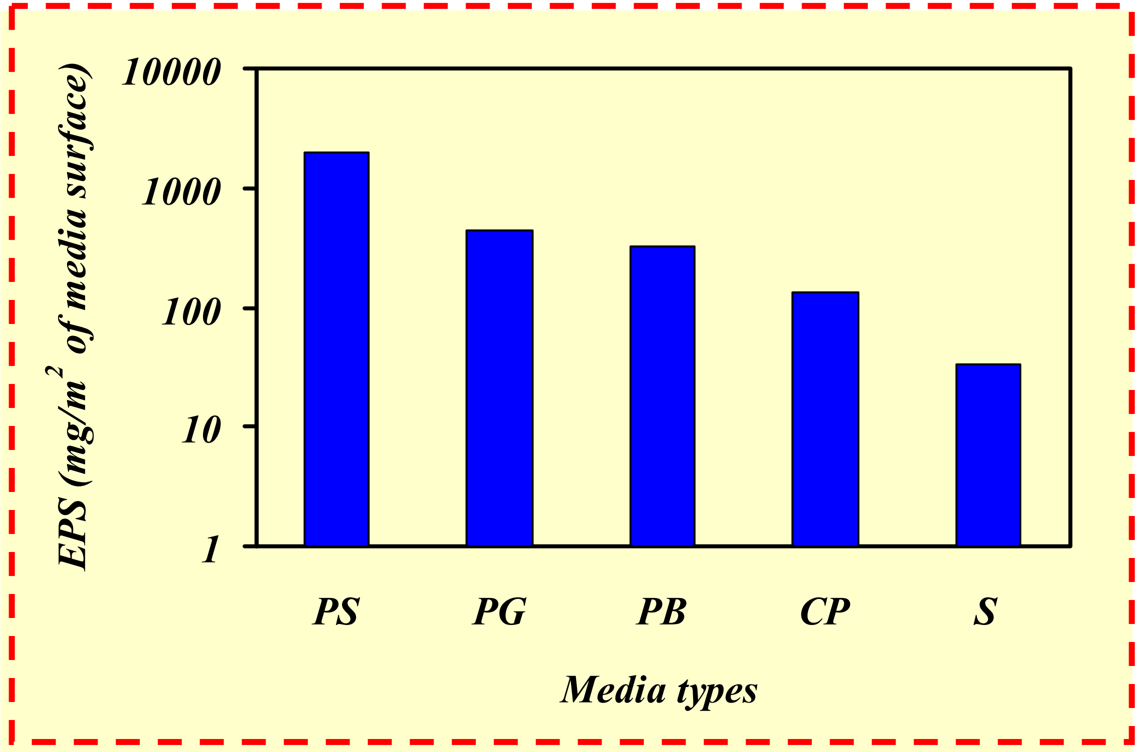


Figure 4.4 EPS content in terms of media surface at different media types

Cylindrical polypropylene was selected due to; floating, well mixing, high surface media and non biodegradable nature.

Conclusions for Preliminary study

- No significant difference in COD removal efficiency was found between the suspended and the attached growth systems.

- The average TKN removal efficiency in the attached growth system was in the range of 83 to 90%.

- There was no significant difference in EPS production in the suspended and the attached growth systems.

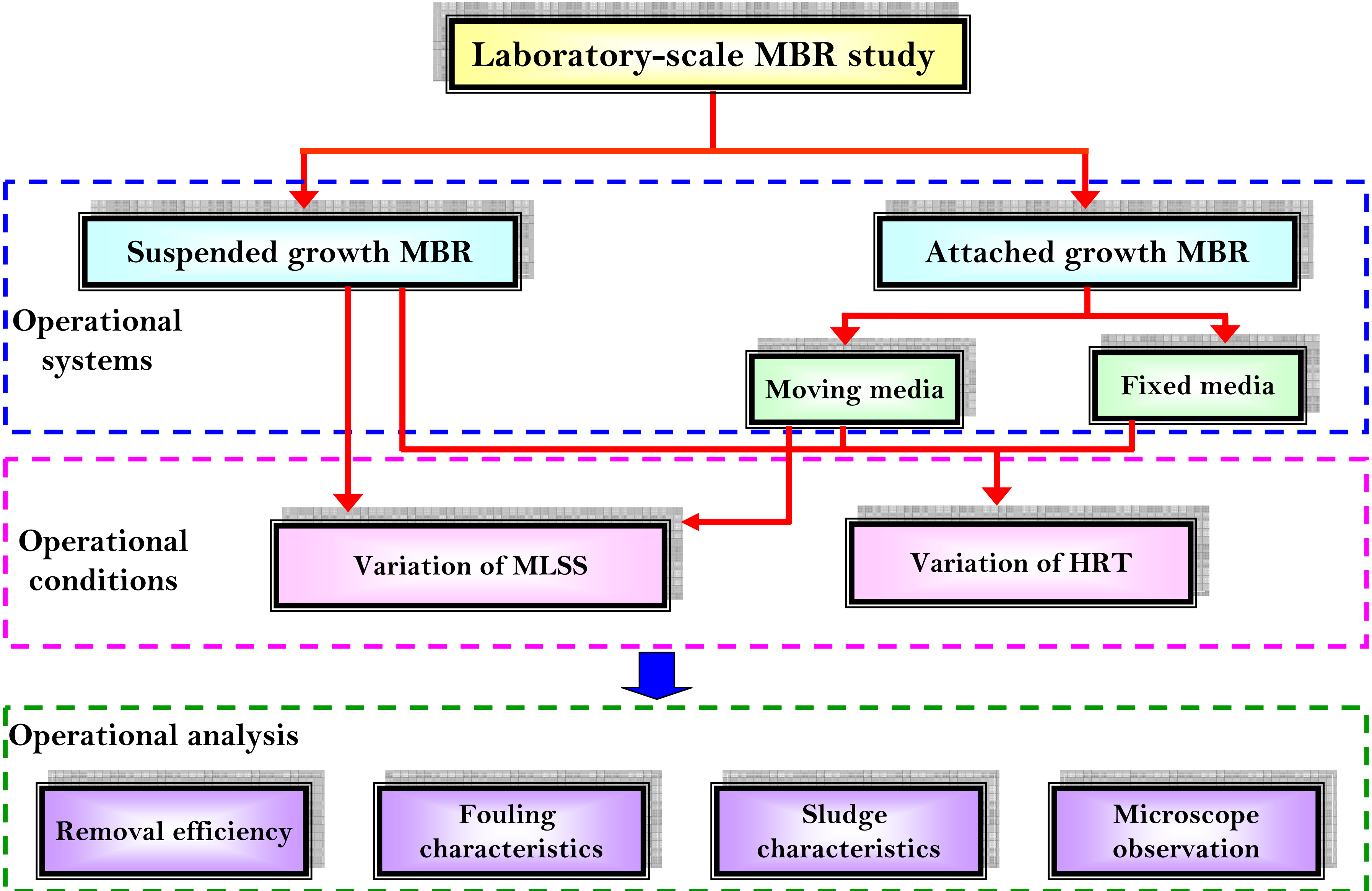
- The productions of EPS and biofilm formation were affected by shape and size characteristics of media used. Cylindrical polypropylene (CP) was most suitable.

Laboratory-scale MBR study

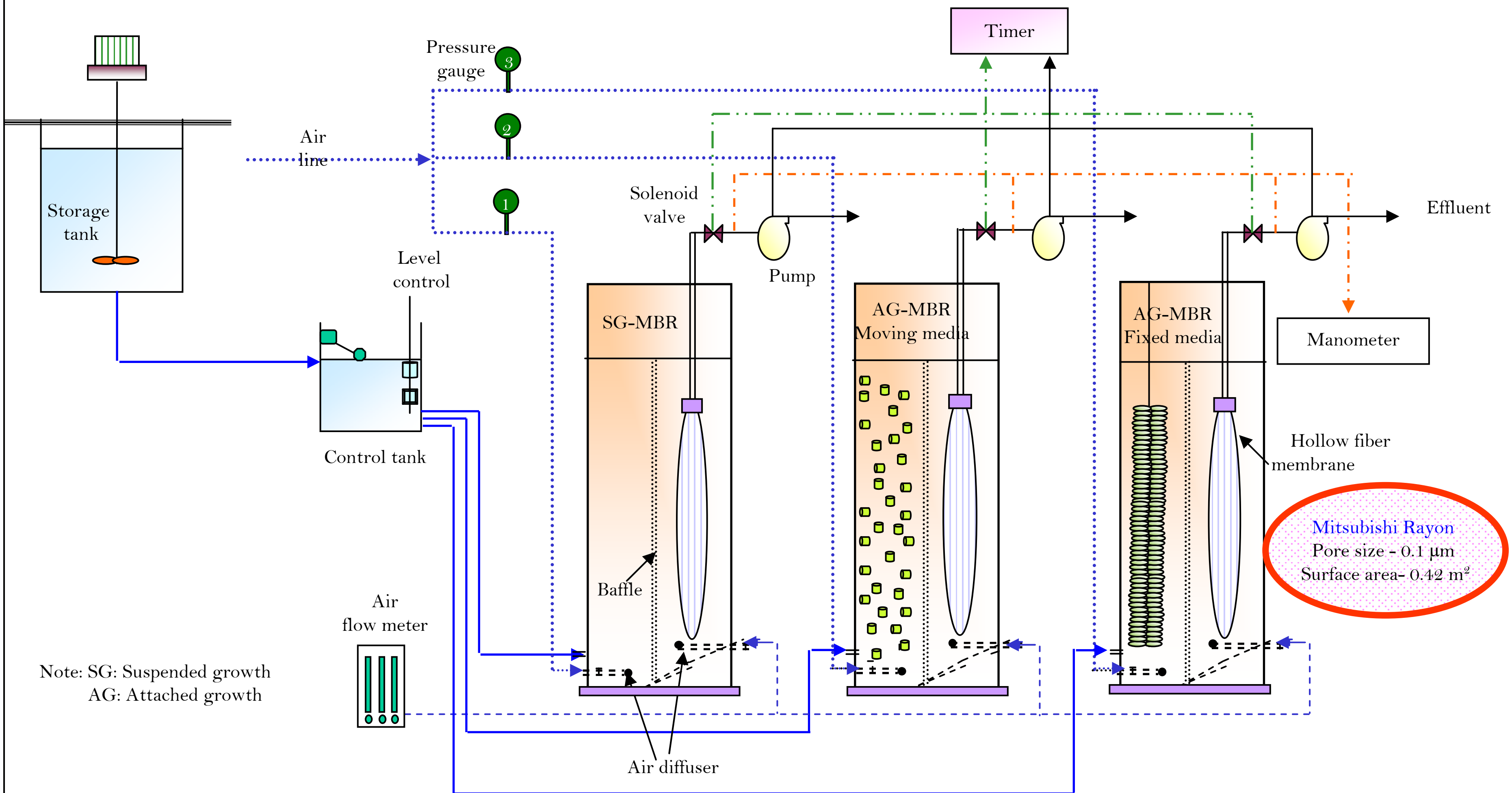
- To investigate effects of operating conditions, such as HRT and MLSS on membrane performance, fouling characteristics, EPS production and sludge properties

- To compare membrane fouling behavior of attached and suspended growth MBRs

Laboratory-scale MBR study



Experimental set-up of MBR



Note: SG: Suspended growth
AG: Attached growth

Effect of Hydraulic Retention Time (HRT)

Table 4.6 COD removal in the MBRs with varying HRT

Item	COD (mg/L) (%Removal efficiency)			
	HRT 8 h	HRT 6 h	HRT 4 h	HRT 2 h
Influent	504	507	522	435
Effluent of suspended growth MBR	16 (97)	12 (98)	19 (96)	15 (97)
Effluent of attached growth MBR with moving media	13 (97)	10 (98)	16 (97)	10 (98)
Effluent of attached growth MBR with fixed media	19 (96)	15 (97)	23 (96)	25 (94)

Effect of HRT

Table 4.7 TKN removal in the MBRs with varying HRT

Item	TKN (mg/L) (%Removal efficiency)			
	HRT 8 h	HRT 6 h	HRT 4 h	HRT 2 h
Influent	**57.5**	**56.8**	**45.4**	**44.8**
Effluent of suspended growth MBR	**2.8 (95)**	**1.3 (98)**	**1.7 (96)**	**2.8 (94)**
Effluent of attached growth MBR with moving media	**2.9 (95)**	**1.3 (98)**	**1.7 (96)**	**2.5 (94)**
Effluent of attached growth MBR with fixed media	**3.3 (94)**	**1.9 (97)**	**2.1 (95)**	**3.4 (92)**

B. EPS Compositions

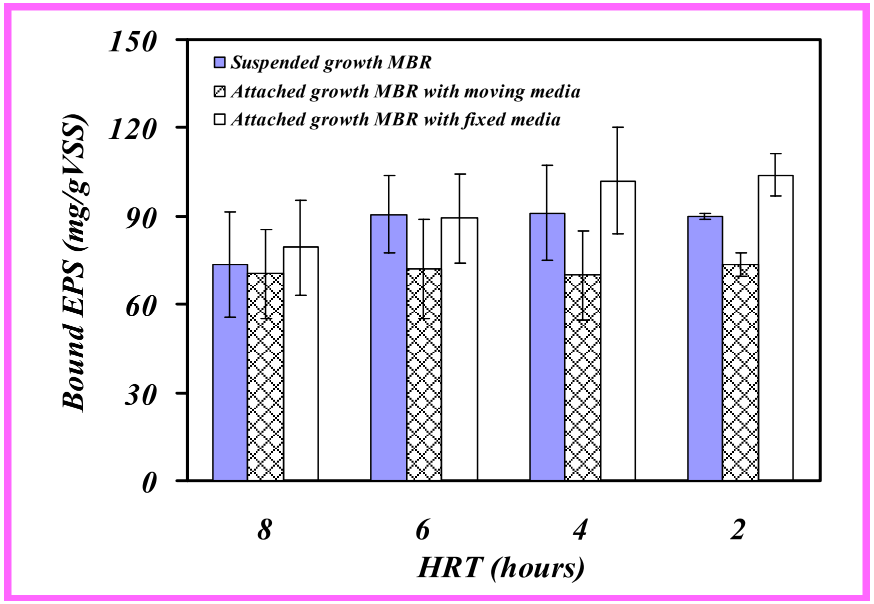


Figure 4.16 Bound EPS concentration in the MBR with varying HRT

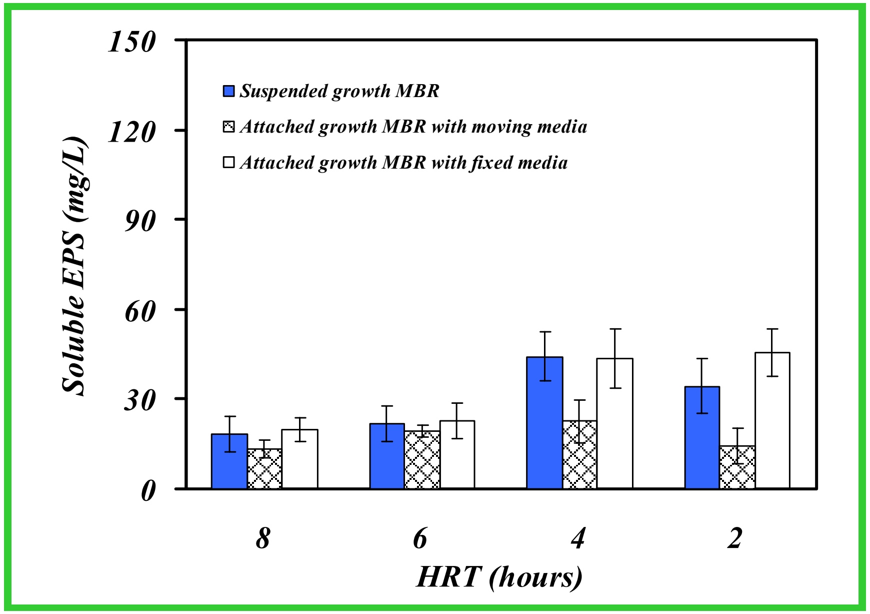


Figure 4.17 Soluble EPS concentration in the MBR with varying HRT

Effect of HRT

Table 4.10 Dewatering properties of sludge (CST-sec.) in the MBR for different HRTs

Reactor	HRT (hours)			
	8	6	4	2
Suspended growth MBR	9.6	18.1	32.7	52.8
Attached growth MBR with moving media	50.0	78.3	86.0	101.3
Attached growth MBR with fixed media	10.0	17.9	20.6	30.2

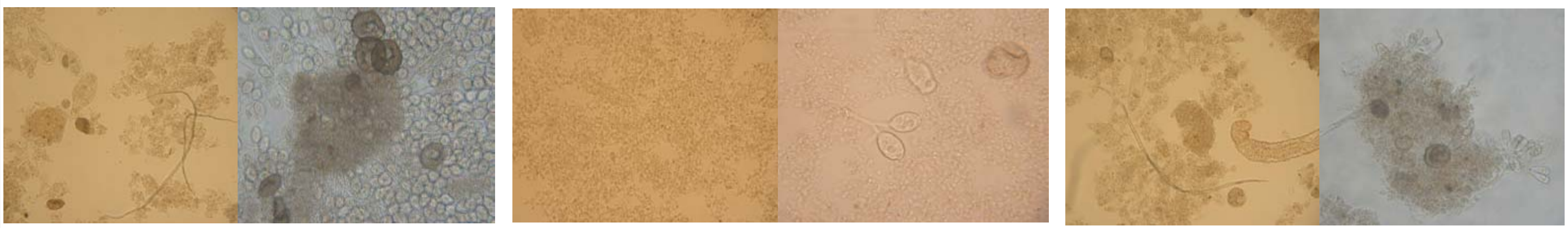
Sludge in the moving media reactor was more difficult to dewatering than that in the other reactors.

Sludge dewatering property was found to increase with decreasing HRT.

Effect of HRT

Table 4.11 Floc morphologies in MBR system

Sample	FI	Description of floc morphology
Suspended growth MBR	2	Compact, round floc with some filamentous and some type of protozoa
Attached growth MBR with moving media	1	Dense and matrix floc, irregular shape floc and small floc size
Attached growth MBR with fixed media	2	Compact, large and round floc with some filamentous embedded within floc and some protozoa



(a) Suspended growth MBR (b) Attached growth MBR with moving media (c) Attached growth MBR with fixed media

Figure 4.26 Sludge particle observed under optical microscope

Conclusions: Effect of HRT

1. COD removal efficiency was greater than 90% with a short HRT.

2. The removal efficiencies of TKN and ammonia were greater than 90% and 94%, respectively at HRT of 2 h.

3. There was no significant difference in bound EPS for all HRT while the soluble EPS was high at short HRT (2 and 4 h).

4. CST value in the attached growth MBR with moving media was higher than that in the suspended growth MBR, and attached growth MBR with fixed media.

5. Sludge morphologies of the three reactors were different in terms of floc shape, floc size and type of microorganism.

Results and Discussions

Effect of Mixed Liquor Suspended Solid (MLSS)

- MLSS was varied at 6, 10 and 15 g/L

B. Membrane Fouling Behavior

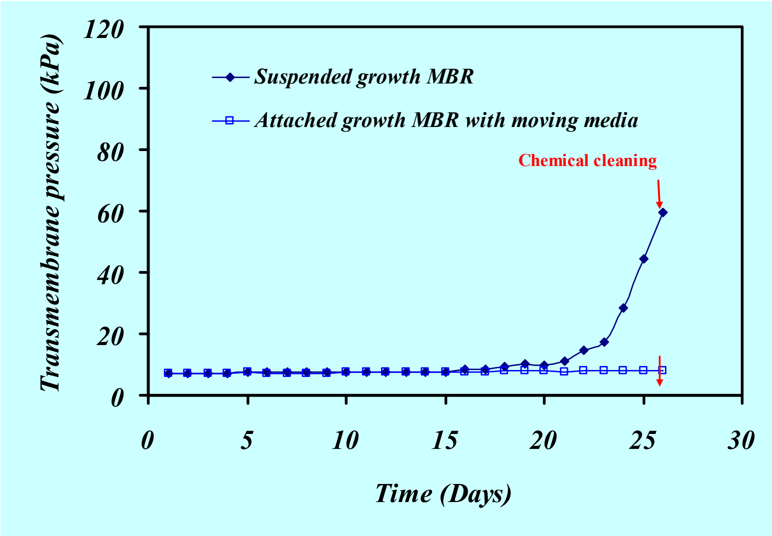


Figure 4.27 TMP changes with time at MLSS of 6 g/L

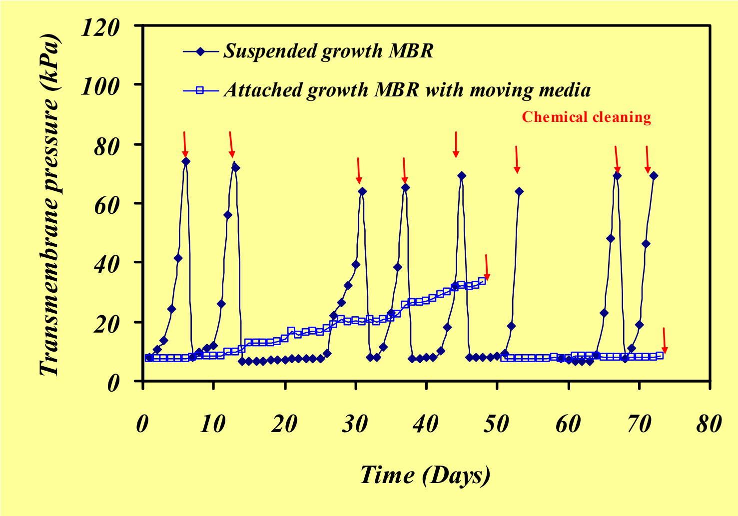


Figure 4.28 TMP changes with time at MLSS of 10 g/L

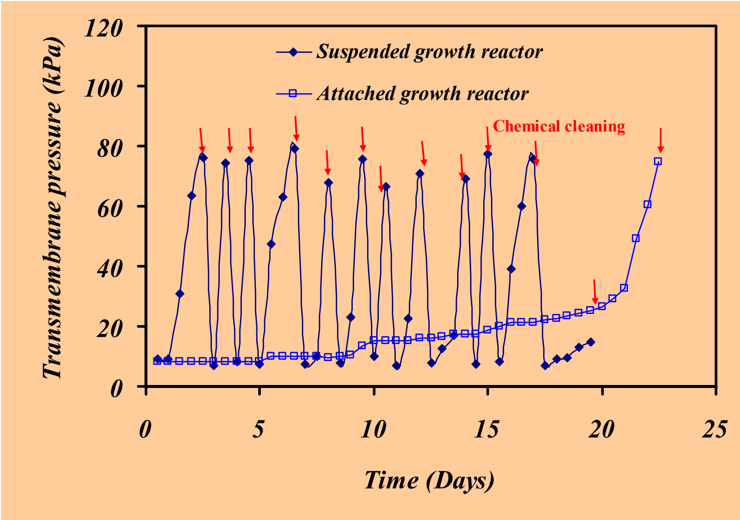


Figure 4.29 TMP changes with time at MLSS of 15 g/L

Table 4.13 Total cake formation on membrane surface for varying MLSS concentration

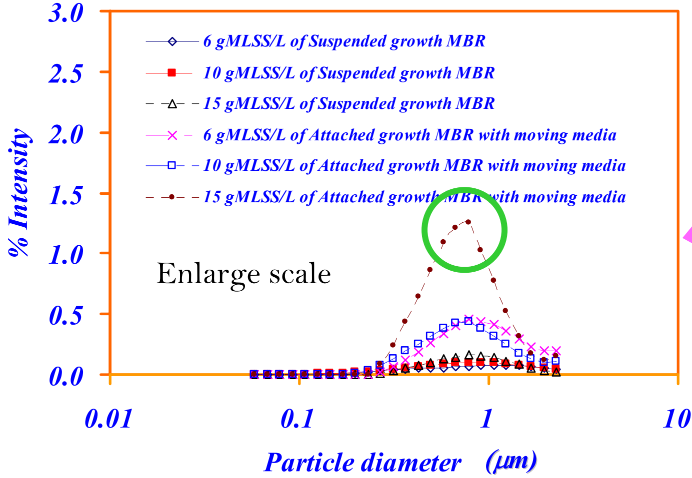
MLSS (g/L)	Total cake formation (g/m²)*	
	Suspended growth MBR	Attached growth MBR
6	5.83	1.73
10	10.38	2.67
15	16.76	8.86

*(weight of the cake / membrane surface area)

Table 4.14 Resistance values for suspended and attached growth reactors at 6, 10 and 15 g/L MLSS

Reactor	MLSS (g/L)	R_t ($*10^{12}$ m^{-1})	R_c ($*10^{12}$ m^{-1})	R_f ($*10^{12}$ m^{-1})	R_m ($*10^{12}$ m^{-1})	R_c/R_t
Suspended growth MBR	6 10 15	34.7 43.5 51.4	33.1 42.4 49.7	0.98 0.46 1.18	0.63 0.63 0.54	0.95 0.97 0.97
Attached growth MBR	6 10 15	2.09 2.55 16.7	0.66 0.84 14.0	0.82 1.06 2.09	0.62 0.65 0.58	0.32 0.33 0.84

Particle size distribution



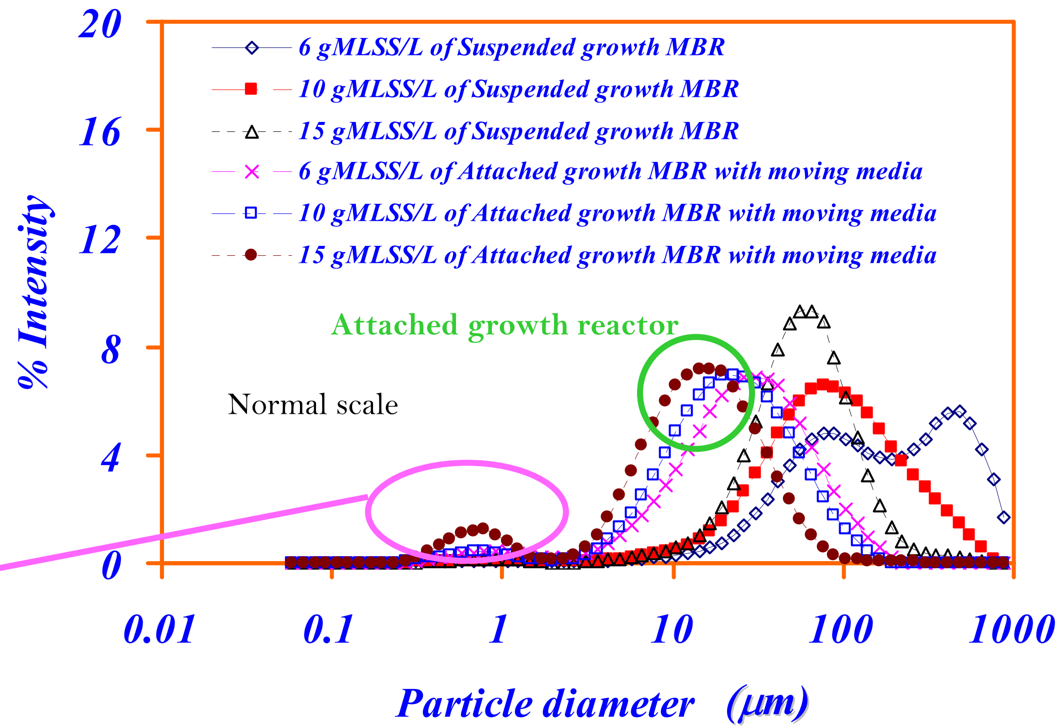


Figure 4.32 Relationship between particle size and MLSS concentration

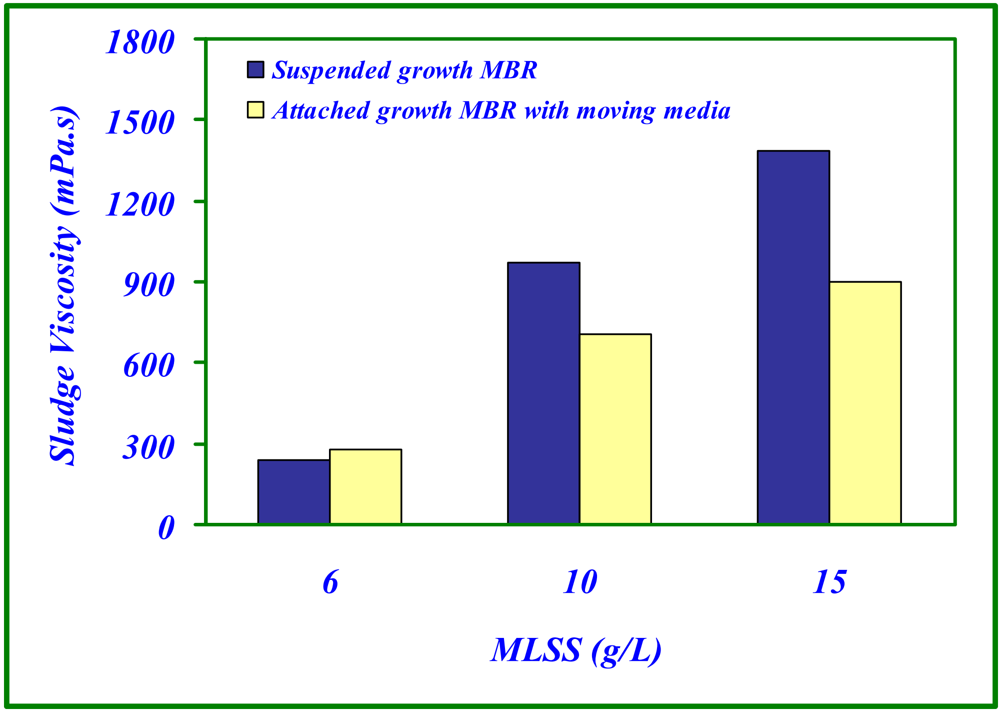


Figure 4.33 Relationship between sludge viscosity and MLSS concentration

Sludge viscosity

Suspended growth reactor: (242, 970 and 1387mPa.s.)

Attached growth reactor: (277 and 705 and 900 mPa.s)

Sludge viscosity increased with increasing MLSS concentration.

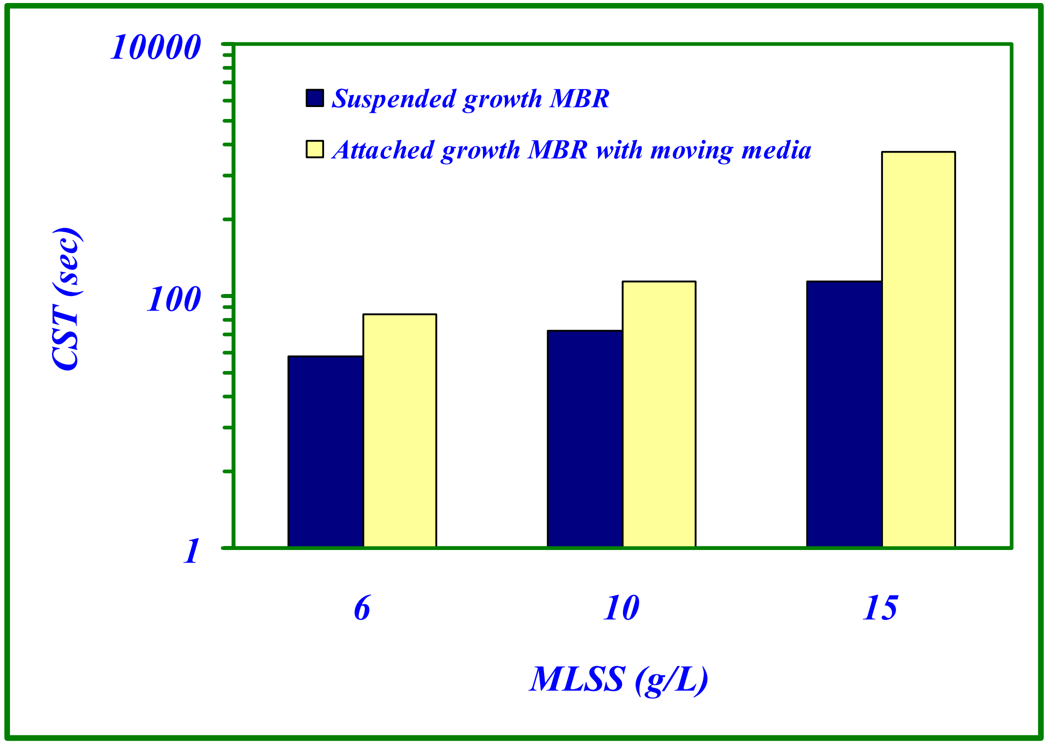


Figure 4.34 Relationship between CST and MLSS concentration

CST

Small floc in attached growth led to a decrease in dewatering property.

D. Bound and Soluble EPS Compositions

Bound EPS compositions

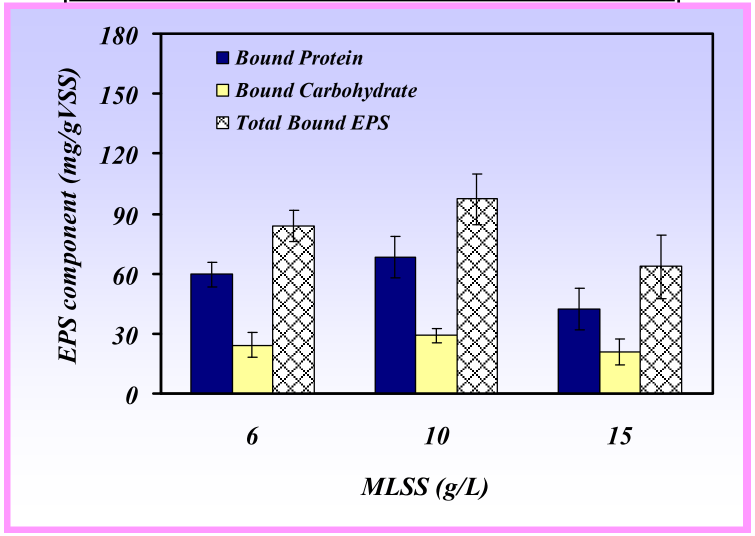


Figure 4.35 Bound EPS components in suspended growth MBR at varying MLSS concentration

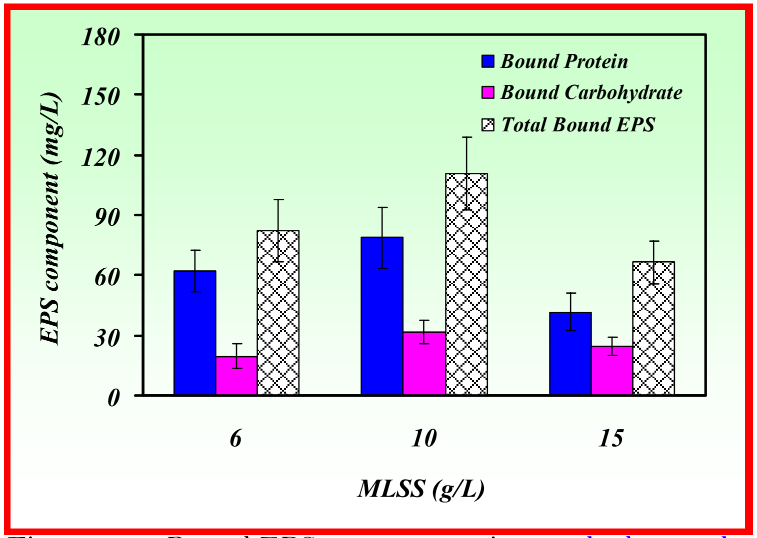


Figure 4.36 Bound EPS components in attached growth MBR at varying MLSS concentration

Soluble EPS compositions

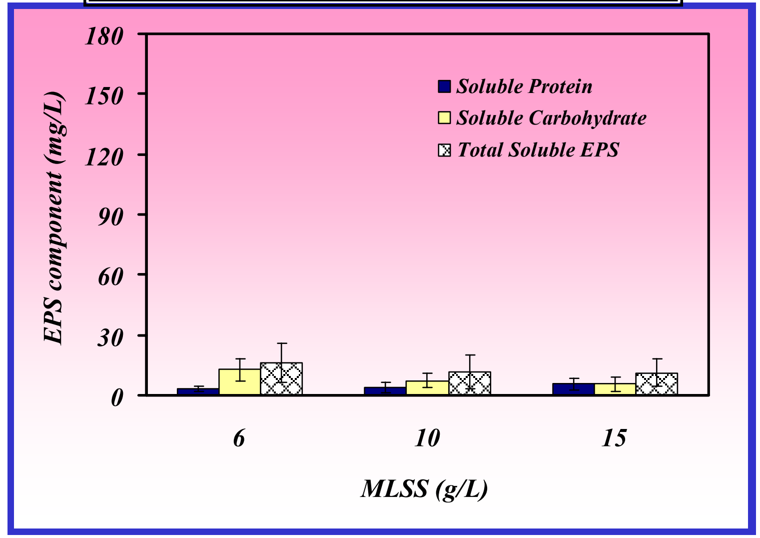


Figure 4.37 Soluble EPS components in suspended growth MBR at varying MLSS concentration

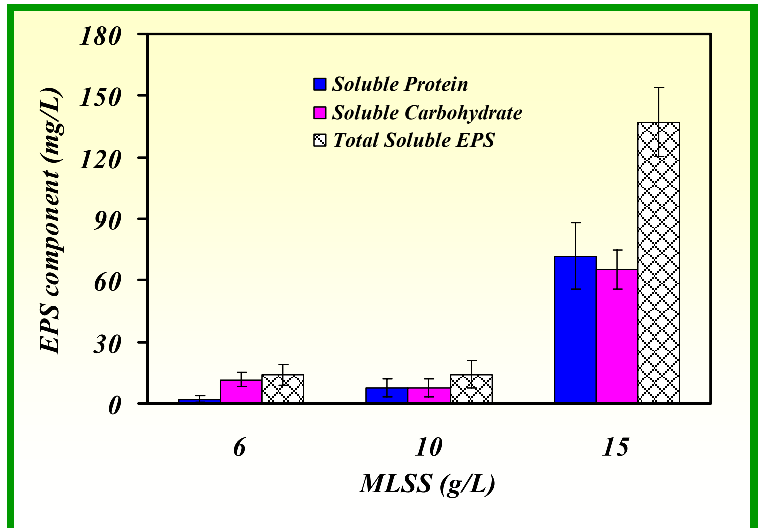


Figure 4.38 Soluble EPS components in attached growth MBR at varying MLSS concentration

Conclusions: Effect of MLSS

1. As the MLSS was increased from 6, 10 and 15 g/L, the TMP values were found to increase due to clogging of the membrane. More membrane fouling in the suspended growth MBR was greater than that in the attached growth MBR.

2. More cake formation was observed on membrane surface in the suspended growth as compared with the attached growth reactors for all MLSS concentrations.

3. The total resistance (*Rt*) in the suspended growth reactor was higher than that in the attached growth reactor. The majority of the membrane fouling in suspended growth reactor was caused by the cake resistance (*Rc*).

4. Membrane fouling increased with increasing MLSS concentration. The cake resistance (*Rc*) increased with the MLSS concentration. The fouling on the membrane was found to be affected by the design of operating system.

Conclusions: Effect of MLSS

5. The attached growth reactor with moving media was found to have lower fouling and prolong filtration as compared to the suspended growth reactor.

6. The bound EPS contents in the suspended growth and attached growth reactors was similar. The amount of soluble EPS at 15 g/L MLSS was higher than that at 6 and 10 g/L MLSS. The EPS was not the main factor to cause fouling.

7. The particle size of the biomass influenced by the movement of the media had a significant effect on the formation of cake layers on the membrane.

Recommendations for Further Study

1. Conduct pilot scale to verify the laboratory-scale results.

2. Comparing removal efficiency and fouling performance between moving bed MBR and anaerobic MBR in the condition of high organic loading.

3. Considering bio-mechanisms of microbial activity and bio-kinetics in the moving bed MBR in more detail and identifying microbial species and their quantification through microbial techniques (FISH, PCR and DGGE).

Originality and novelty of this work

Experimental technique: The operating system and design of MBR are novel and quite different from the other researches. That is, the media is moving during the operation. The moving media was coupled with the membrane bioreactor into a single unit.

Experimental explanation: The proposed explanation is based on the movement of media which produced small particles in the attached growth system leading to high cake porosity, small cake thickness and low cake resistance in the attached growth MBR.

Outcome and contribution: The performance and lifetime of the membrane used in MBR could be improved by the use of attached growth system with the presence of moving media. Attached growth system can withstand high organic loading and consequently require small footprint making it feasible for domestic and industrial wastewater treatment.

Conclusion: The attached growth MBR exhibited less fouling than the suspended growth MBR.

Publication for this study

Sombatsompop, K., Visvanathan, C. and Ben, Aim, R. 2006. Evaluation of biofouling phenomenon in suspended and attached growth membrane bioreactor systems. *Desalination,* 201, 138-149.

Sombatsompop, K. M. and Visvanathan, C. 2005. Evaluation of biofouling phenomenon in suspended and attached growth membrane bioreactor systems. Proceedings of 3rd Regional Symposium on Membrane Science & Technology: Membrane Technology for Industry and Environmental Protection Institute Teknologi Bandung, Indonesia, 26-27 April.

Manoonpong, K. and Visvanathan, C. 2004. Fouling behavior in attached and suspended growth membrane bioreactor. AIT-KIST International Joint Symposium, Asian Institute of Technology, Pathumthani, Thailand, 20-21 May.

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