Submerged Membrane Bioreactor Hybrid System for Wastewater Treatment using Porous Membrane

Young Moo Lee, Jin Kie Shim*

Submerged Membrane Bioreactor Hybrid System for Wastewater Treatment using Porous Membrane

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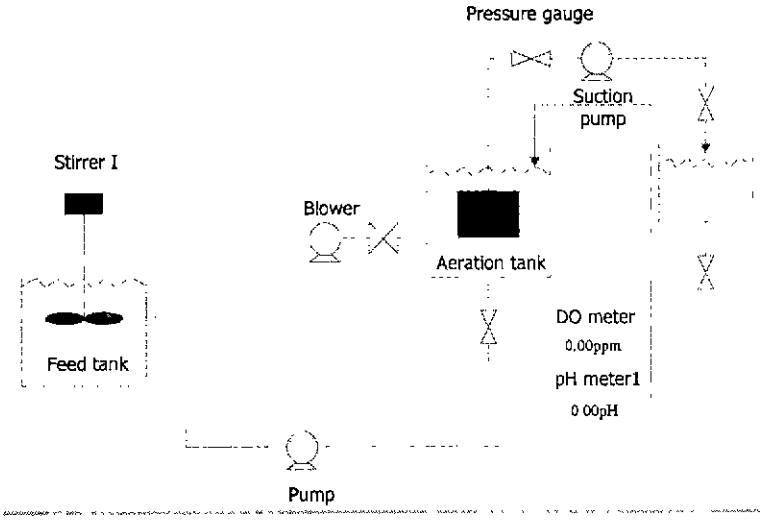
High Strength Wastewater Treatment using Submerged Membrane Bioreactor

Aerobic membrane bioreactor system



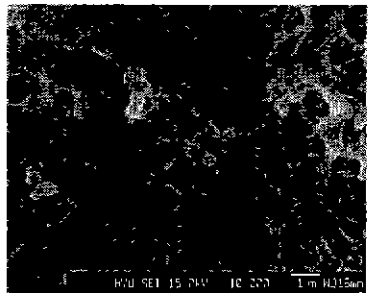
Experimental condition of membrane bioreactor

Working Volume	21 L
HRT	13 ~ 15 hr
SRT	15 ~ 40 days
MLSS	8,000 ~ 16,000
Air flow rate	5 ~ 15 L/min
Influent COD_{cr}	800 ~ 1,600 mg/L

Characterization of membrane

Type	Plate & Frame
Filtration system	Suction or Gravity
Pore size	0.4 μm
Material	Synthetic resin
Effective surface area	0.1 m^2

FE-SEM picture of membrane



Membrane bioreactors of rectangular type

Reactors	L(cm)	W(cm)	H(cm)	Vol.(L)	A_r/A_d	Air Bubble	Day of Operation
R1	40	13.5	39	21	0.219	fine bubble	0-247
R2	22	6	160	21	0.636	fine bubble	0-50
R3	22	10	115	26	0.288	coarse bubble	51-116

* A_r cross-sectional area of the riser (upflow section of air bubble & air-lifted liquid)

A_d : cross-sectional area of the downcomer (downflow section of degassed liquid)

Feed composition of synthetic wastewater

Unit mg/L

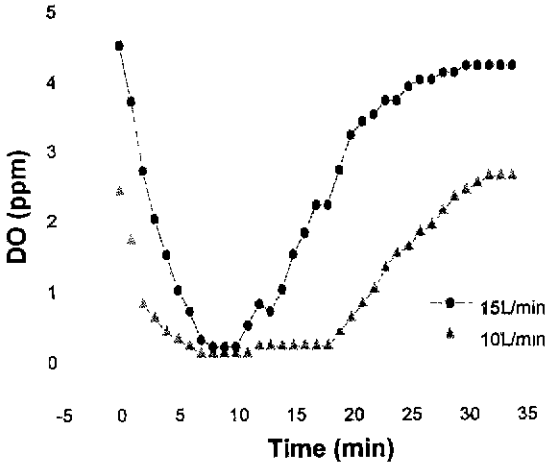
Component	Run 1	Run 2	Run 3	Run 4
Glucose	673 3	808 0	942 7	1077 3
Glutamic Acid	286 7	344 0	401 3	458 7
CH_3COONH_4	220 0	264 0	308 0	352 0
$NaHCO_3$	666 7	666 7	666 7	666 7
NH_4Cl	33.3	40 0	46 7	53 3
KH_2PO_4	50 0	60 0	70 0	80 0
K_2HPO_4	66 7	80 0	93.3	106.7
$MgSO_4 7H_2O$	26 7	32 0	37 3	42 7
$MnSO4 H_2O$	8 3	10 0	11 7	13 3
$FeCl_3.6H_2O$	1 3	1 6	1 9	2 1
$CaCl_2 2H_2O$	16 7	20 0	23 3	26 7
NaCl	20 0	24 0	28 0	32 0
COD	1,000	1,200	1,400	1,600

Operation period and air flow rate of reactor 1-3

Operational sequence (Reactor 1)	day of operation		
	1-54	55-110	111-247
suction	7min	8min	8min
idle	3min	2min	2min
air flow rate	8L	15L	10L

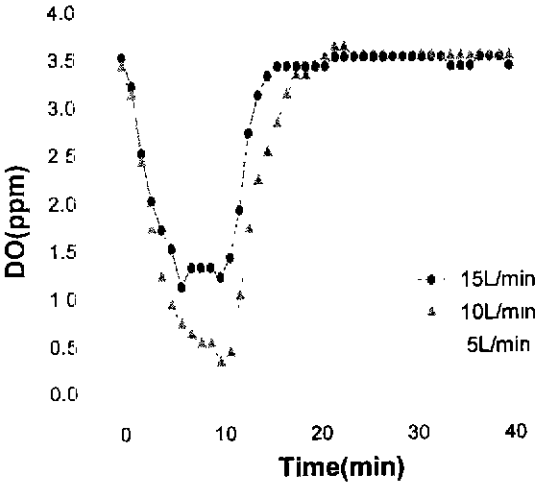
Operational sequence (Reactor 2-3)	day of operation	
	1-50(RX2)	51-116(RX3)
suction	7min	7min
idle	3min	3min
air flow rate	8L	10L

DO variation with time in reactor 1



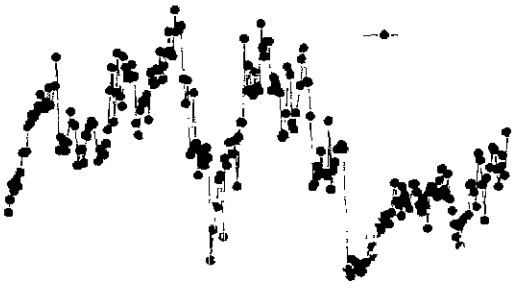
- Role of the supplied air
  - → Cleaning the membrane
  - → The oxygen supply to microorganism for organic decomposition
- Fine air diffuser was installed
- MLSS : 8,500 mg/l
- Feed rate of influent : 80 ml/min
- COD_{cr} of feed: 1,500 mg/l
- Intermittent operation of suction pump
  - → 7 min – suction, 3 min – stop

DO variation with time in reactor 3

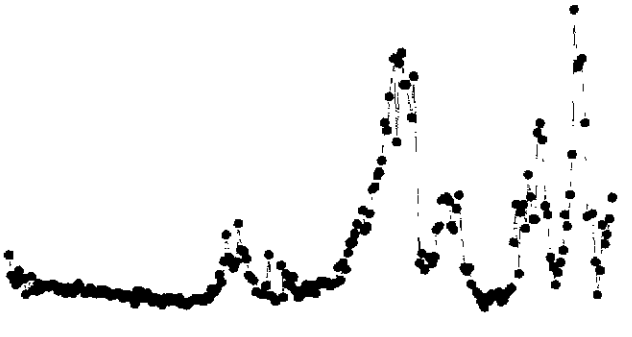


- Coarse air diffuser was installed
- MLSS : 11,000 mg/l
- Feed rate of influent : 80 ml/min
- COD_{cr} of feed: 1,500 mg/l
- Intermittent operation of suction pump
  - → 7 min – suction, 3 min – stop

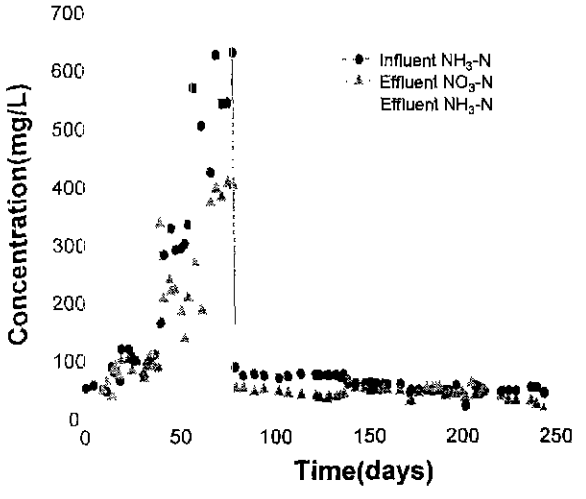
MLSS and F/M ratio variation with time in reactor 1



SVI variation with time in reactor 1

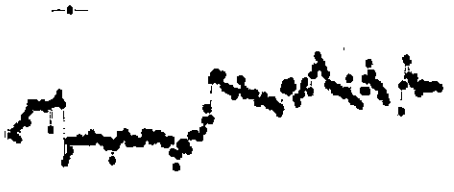


Comparison of nitrogen concentration for feed and effluent in reactor 1



- **Influent NH_3-N**
  - **Until 80th day, the influent NH_3-N concentration was changed**
  - **To observe the influent NH_3-N concentration effect**
  - **The influent NH_3-N concentration does not effect the NH_3-N removal efficiency**
- **Effluent average NH_3-N**
  - **10 ppm**
- **NH_3-N removal efficiency**
  - **around 98%**

Flux and TMP variation with time in reactor 1

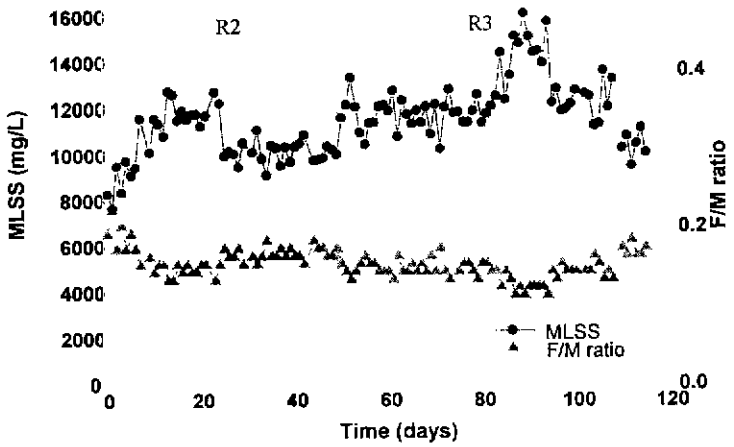


- Around 130th day, TMP increasing
  - **Due to sludge bulking (SVI increasing)**
- On 150th day, physical cleaning
  - **Cleaning the membrane with the sponge**
  - **Within 4 days, fouling was observed**
- On 160th day, chemical cleaning
  - 0.3 wt% **NaOCl and oxalic acid for 3 hours each**
  - **Within 20 days, fouling was observed**
- On 160th day, chemical cleaning
  - 1 wt% **NaOCl and oxalic acid for 3 hours each**

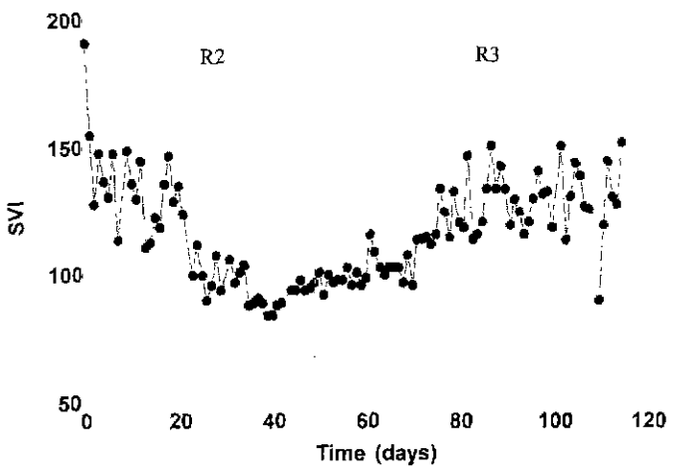
COD_{cr} variation with time in reactor 1

- Influent COD_{cr}
  - → To observe the influent COD_{cr} concentration effect
  - → The influent COD_{cr} concentration does not effect the COD_{cr} removal efficiency
- Effluent average COD_{cr}
  - → 5 ppm
- COD_{cr} removal efficiency
  - → around 98%

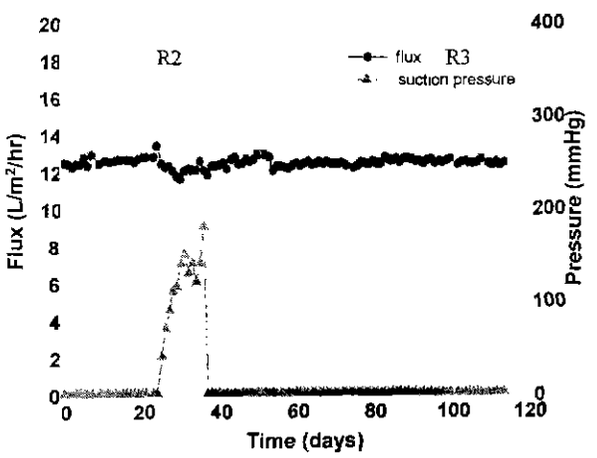
MLSS and F/M ratio variation with time in reactor 2-3



SVI variation with time in reactor 2-3

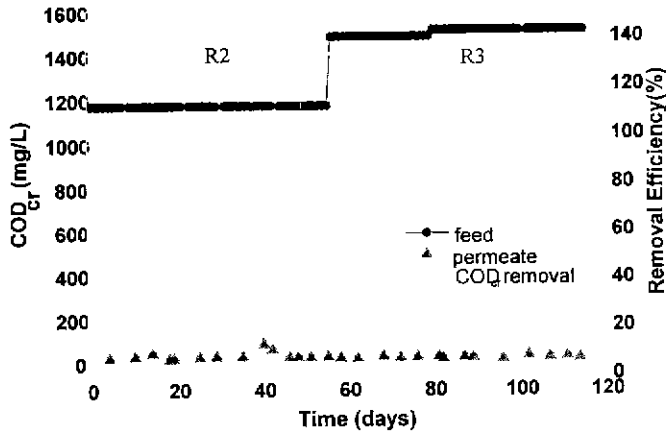


Flux and TMP variation with time in reactor 2-3



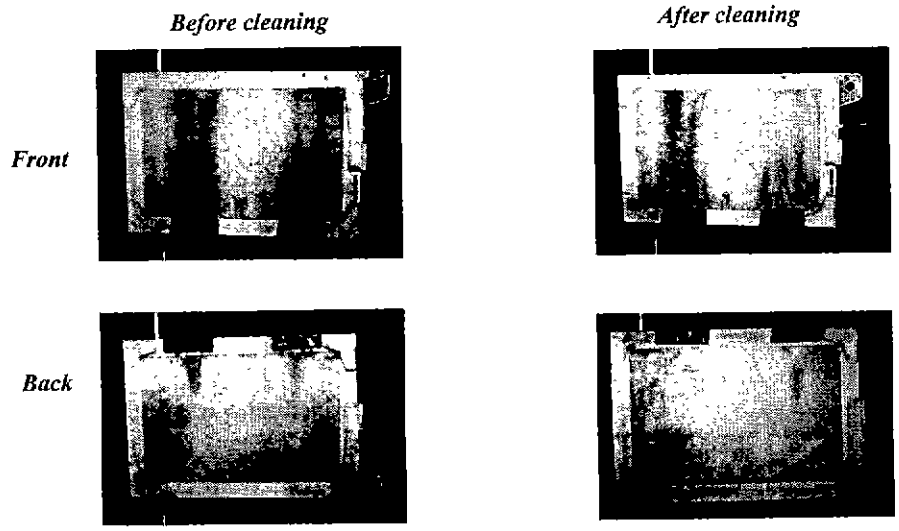
- Until 23 days, flux and TMP were constant
- After 23th day, TMP was steeply increasing
- Cleaning on 38th day
  → NaOCl and oxalic acid
  → Until the last day of the operation, fouling was not observed
- TMP increasing was not observed in reactor 3
  → Reactor geometry is important

COD_{cr} variation with time in reactor 2-3

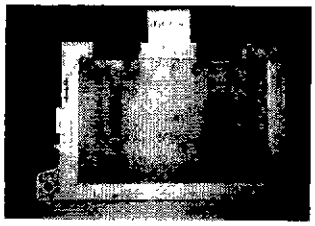
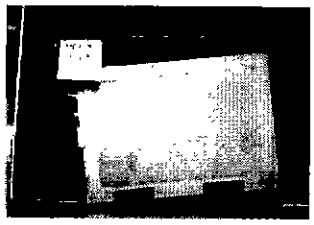
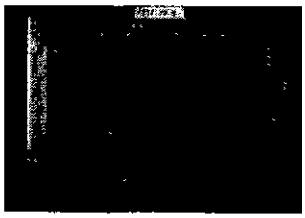
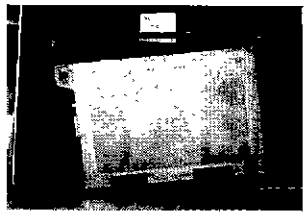


- Influent COD_{cr}
  - → 1,100 ~ 1,500 ppm
  - → average : 700 ppm
- Effluent average COD_{cr}
  - → Below 20 ppm
- COD_{cr} removal efficiency
  - → over 98%

Physical Cleaning



Chemical Cleaning - 1wt% NaOCl & Oxalic acid

	Before cleaning	*After cleaning for 12hrs*
Front		
Back		

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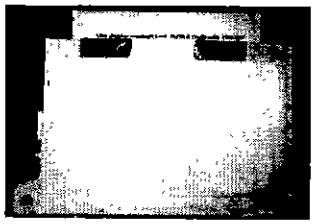
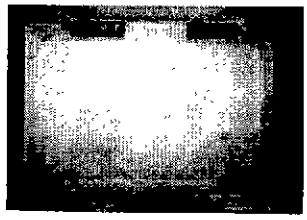
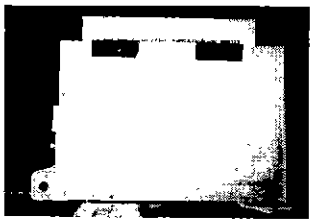
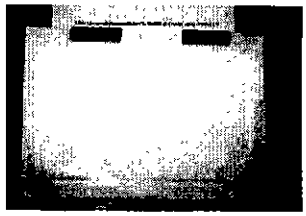
Chemical Cleaning

	After cleaning for 24hrs	*After cleaning for 96hrs*
Front		
Back		

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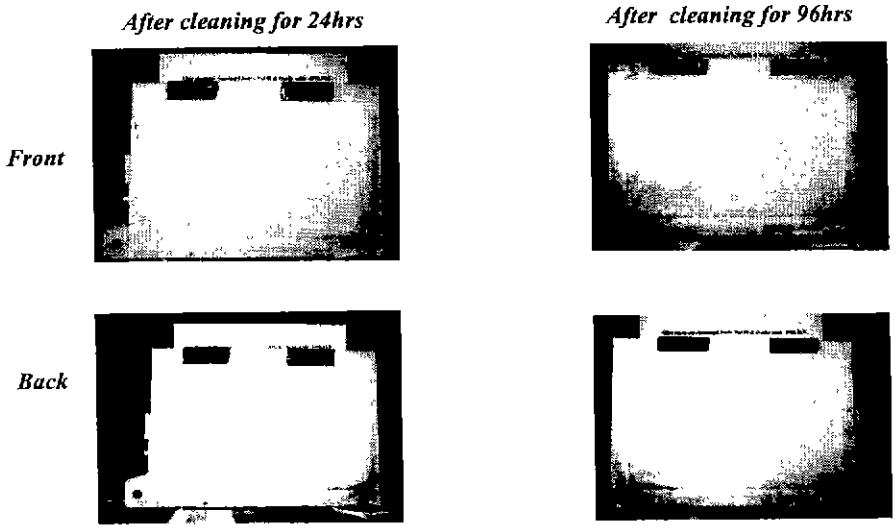
Chemical Cleaning



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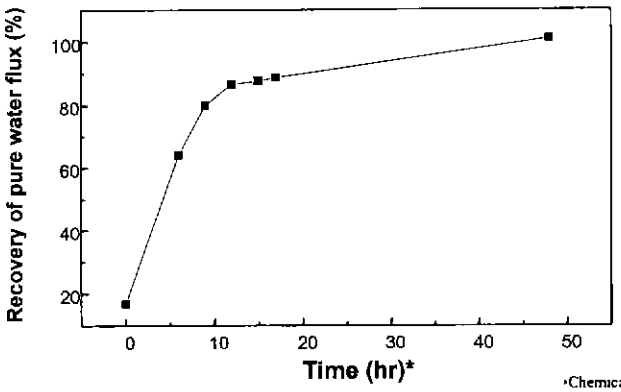
Recovery of pure water flux after chemical washing



- Chemical solution 1wt% NaOCl aqueous solution
  1wt% Oxalic acid aqueous solution
- Time Immersing time of membrane in each chemical solution
- Recovery of pure water flux (%) = J_t/J_i x 100
  J_i = initial pure water flux of membrane
  J_t = pure water flux of membrane at predetermined time after chemical washing

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Treatment of High Strength Nitrogen Wastewater by Submerged Hollow Fiber Membrane Bioreactor

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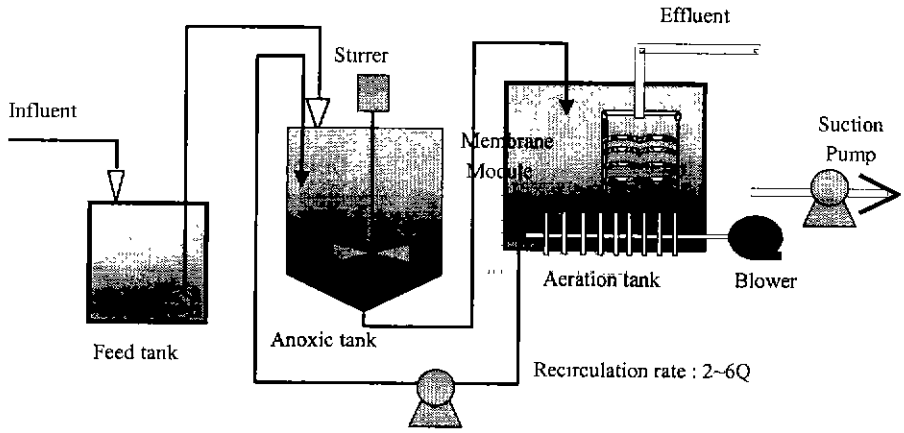
Membrane bioreactor system flow diagram



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Experimental conditions

✓ **Operating conditions of MBR**

Anoxic Volume (L)	5 ~ 15
Oxic Volume (L)	5 ~ 15
HRT (hr)	11 ~ 15
SRT (days)	20 ~ 30
Recirculation Rate	2Q ~ 6Q
Air Flow Rate (L/min)	15 ~ 20
MLSS (mg/L)	6000 ~ 14000
Period	≅ One year
Temperature (˚C)	20 ~ 27

✓ **Characterization of Membrane**

Type	Hollow Fiber
Filtration	Intermittent filtration by suction
Pore Size	0.1 μm
Material	Hydrophilized PE
Effective Surface Area	0.2 m^2
Limiting Variables	pH 2~12, below 40 °C

✓ **Synthetic Wastewater** unit : mg/L

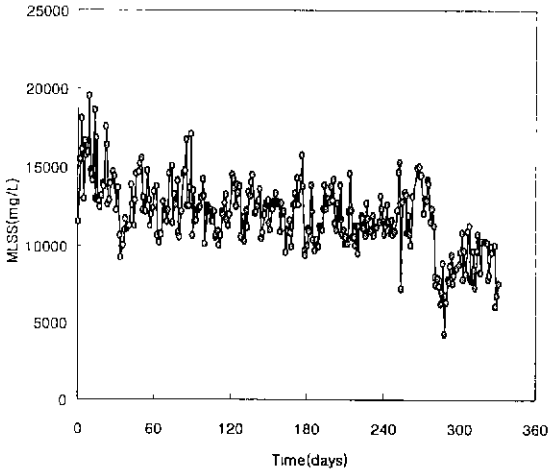
BOD	900~1100
CODcr	1200~1400
T-N	200~300
NH_3-N	175~280

✓ Composition of synthetic wastewater

(basis: COD 1,200 mg/l, T-N 200 mg/l)

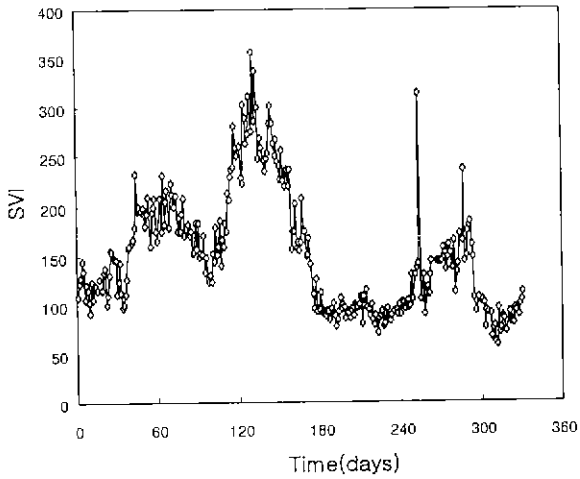
Component	Concentration (mg/l)
Glucose	**808**
Glutamic acid	**345**
CH_3COONH_4	**265**
$NaHCO_3$	**750 - 2,000**
NH_4Cl	**888**
KH_2PO_4	**60**
K_2HPO_4	**80**
$MgSO_4 \cdot 7H_2O$	**33**
$MnSO_4 \cdot H_2O$	**10**
$FeCl_3 \cdot 6H_2O$	**3**
$CaCl_2 \cdot 2H_2O$	**20**
NaCl	**25**

MLSS variation of aeration tank with time



- ➢ Yamamoto, K. et al.
  - ➔ Critical MLSS concentration : 30,000 ~ 40,000ppm for tannery and domestic wastewater
- ➢ Stabilization of MLSS
  - ➔ 10,000 ~ 14,000 ppm
- ➢ After 281st day
  - ➔ Feeding higher nitrogen loading
  - ➔ MLSS was reduced to 8,000ppm

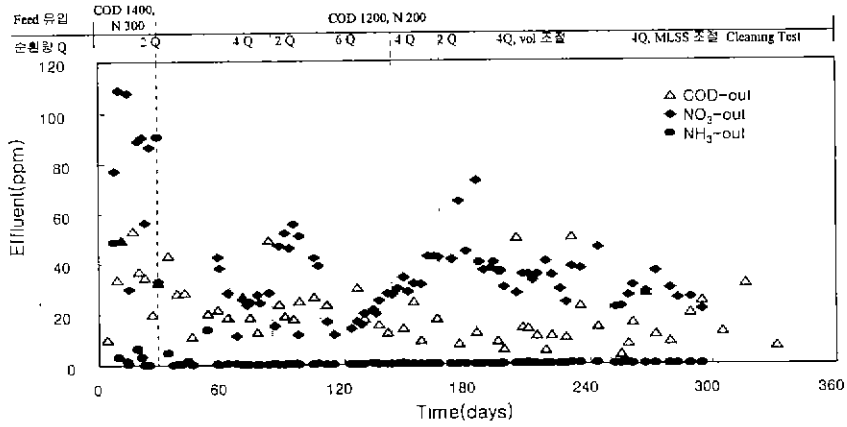
SVI variation of aeration tank with time



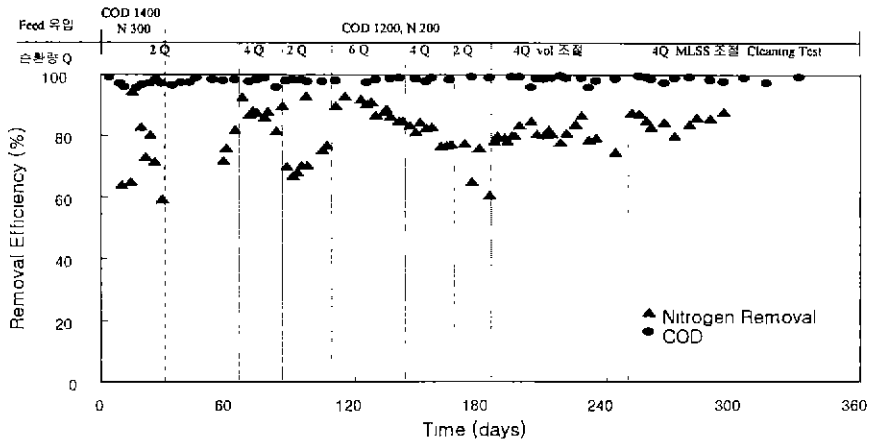
- Measurement of SVI
  → To observe the sludge condition and settleability
  → Biomass condition influences the membrane performance

- After 170 days
  → SVI was steady around 100 for 80 days (settlement)

Effluent concentration variation with time for different operating conditions



Removal efficiency of organics/nitrogen in effluent for different operating conditions



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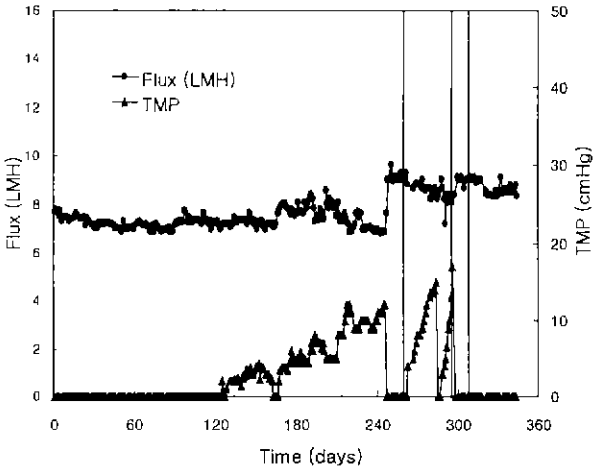
TMP & Flux variation with time for Reactor 4



- Until 125 days, flux and TMP were constant
- After 125th day, TMP was gradually increasing
- 1st Cleaning on 247th day
  - → NaOCl
  - → Within 20 days, fouling was observed
- 2nd Cleaning on 284th day
  - → NaOCl and NaOH
  - → Within 2 days, fouling was observed
- 3rd Cleaning on 296th day
  - → NaOCl, NaOH and oxalic acid
  - → Until the last day of the operation, fouling was not observed

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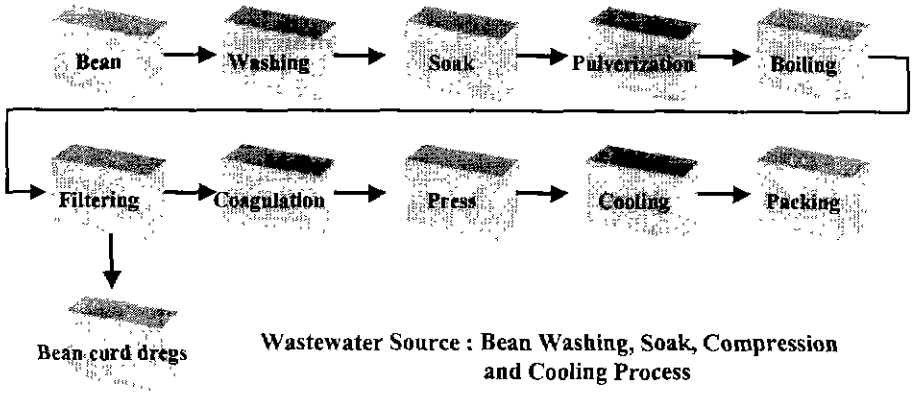
Analysis of aeration tank/denitrification tank with recirculation rate

Influent condition CODcr 1200, T-N 200

	Recirculation rate	6Q	4Q	2Q
Denitrification rate(%)	Aeration tank	90.2	82.7	72.7
	Denitrification tank	85.5	78.3	82.0
COD_{cr} (ppm)	Aeration tank	20.0	16.6	10.4
	Denitrification tank	202	286	176
NO_2-N (ppm)	Aeration tank	10.5	1.4	2.5
	Denitrification tank	27.0	18.3	12.3
NO_3-N(ppm)	Aeration tank	19.8	30.4	45.4
	Denitrification tank	0.8	0.7	0.8

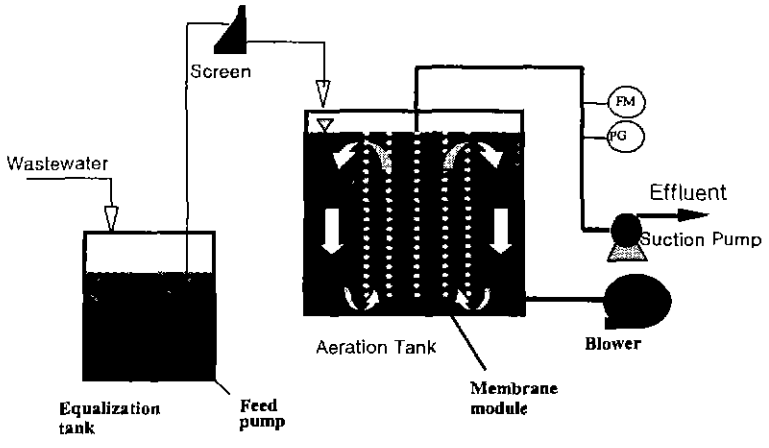
Food Wastewater Treatment using Pilot-scale Submerged Membrane Bioreactor

Bean curd manufacture process



Wastewater Source : Bean Washing, Soak, Compression and Cooling Process

Schematic diagram of pilot-scale SMBR



Specification of pilot-scale SMBR

• Target Water Quality

	Influent	Effluent
Capacity	4000 L/day	4000 L/day
BOD	800 mg/L	10 mg/L
COD	250 mg/L	20 mg/L
SS	300 mg/L	N.D
T-N	30-40 mg/L	< 10 mg/L

• Membrane Characteristics

Type	Plate & Frame
Filtration System	Suction
Pore size	0.4 ㎛
Flux	700 lmh at 1atm
Material	Synthetic Resin
Membrane area	12 ㎡
Module No.	30 ea (0.4 ㎡/ea)

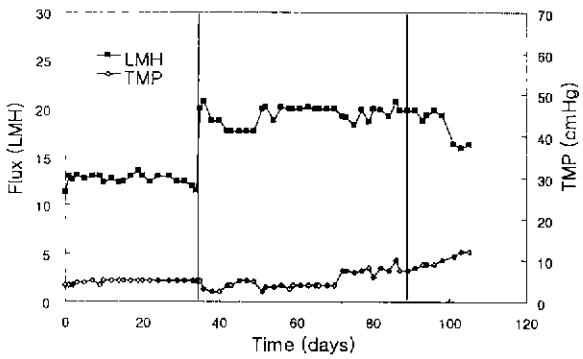
Operation condition of pilot-scale SMBR

Working volume	**2.2 ~ 2.7 m3**
HRT	**12 ~ 24 hr**
SRT	**20 ~ 60 days**
MLSS	**6000 ~ 13000 ppm**
Air flow	**10 ~ 20 Nm^3/hr**
pH	**5.8 ~ 7.5**
Operational Sequence	**Intermittent filtration by suction (8min., 2.5min)**

Water quality of influent and effluent

	Range of influent	Average of influent	Range of effluent	Average of effluent	Removal Efficiency
SS	20 ~ 50	250	≒ 0	≒ 0	≒ 100
BOD	160 ~ 440	330	0.4 ~ 3.4	1.7	99.5
CODcr	300 ~ 1200	700	1 ~ 21	6.5	99.1
T-N	16 ~ 46	33	16 ~ 34	24.7	25.2
NH_3-N	0.5 ~ 4 8	2.2	0.02 ~ 0.8	0.2	91.9
NO_3-N	13 ~ 43	28	14 ~ 34	20.5	26.8

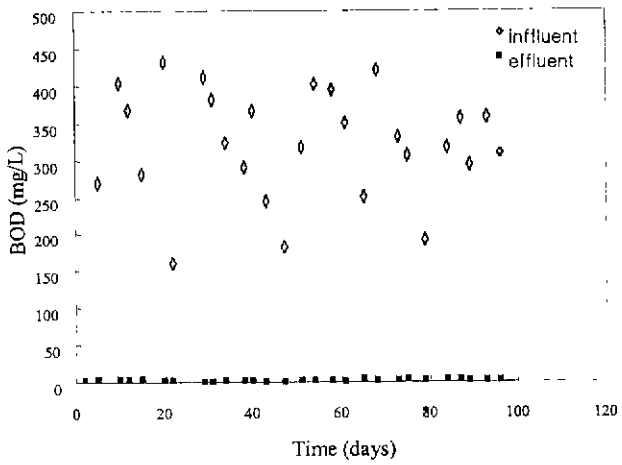
Flux and TMP variation with time



Initial flux : 13 LMH
Effluent flow rate was controlled by a control valve and the inverter of the suction pump.
Until 35 days : stabilization term
After 35 days : flux - 20 LMH
After 100 days : flux decline was observed (15 ~ 16 LMH)

Until 100 days : TMP was gradually increased from 2 to 8 cmHg
After 100 days : TMP was steeply increased

BOD_5 variation with time



- Influent BOD_5
  - → 150 ~ 500 ppm
  - → average : 330 ppm
- Effluent average BOD_5
  - → 1.7 ppm
- BOD_5 removal efficiency
  - → over 99%

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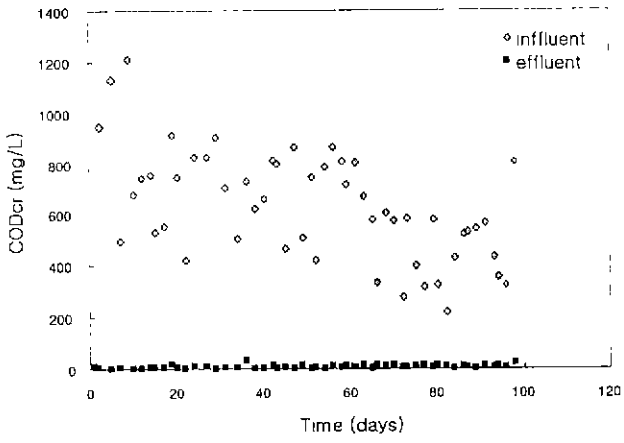
COD_{cr} variation with time



- Influent COD_{cr}
  - → 200 ~ 1,200 ppm
  - → average : 700 ppm
- Effluent average COD_{cr}
  - → 6.5 ppm
- COD_{cr} removal efficiency
  - → over 99%

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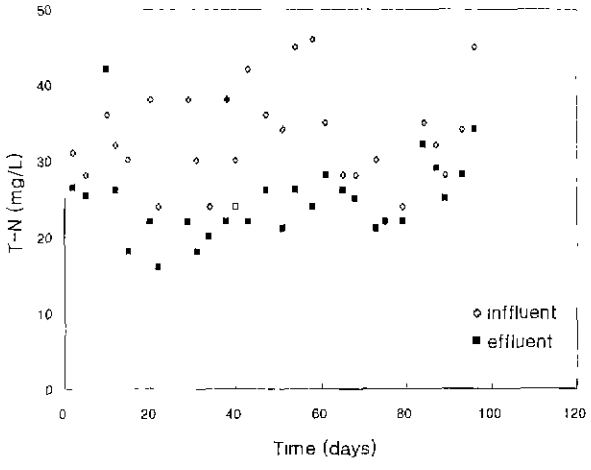
T-N variation with time



- Influent T-N
  - → 25 ~ 45 ppm
  - →average : 35 ppm
- Effluent average T-N
  - →25 ppm
- T-N removal efficiency
  - → around 25%

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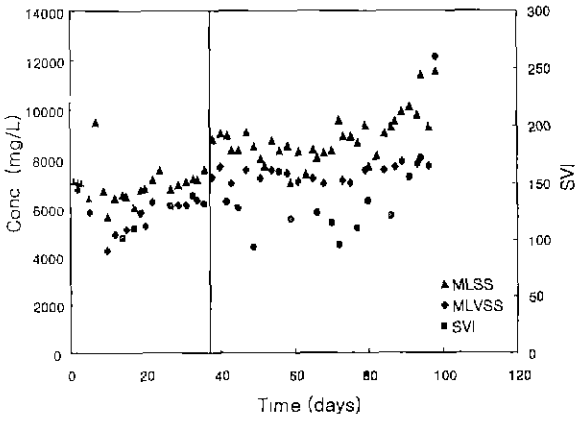
MLSS, MLVSS and SVI variation with time



- MLSS
  - → Until 35 days, increasing steadily
  - → Sudden increasing on 40th days
- SVI
  - → At around 100th days, high SVI caused the large TMP rising.

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