How to Control MBR

Biological aspects Hydrodynamic aspects

> Roger BEN AIM INSA Toulouse benaim@insa-tlse.fr

For a given effluent

- SRT is the only operational parameter which is quite different from conventional activated sludge process where the sludge recycling flowrate was an additional parameter.
- The consequences of a change in SRT are not immediate .

Why changing the SRT

- For trying to get constant F/M ratio despite the variation of the effluent (flowrate and/or concentration) : this implies a variation of the biomass concentration.
- Or for trying to get a constant biomass concentration which implies a variation of the F/M ratio.
- What is the best policy?

Due to the inerty of the biomass

- This policy would need not a steady state model but a dynamic model.
- In fact a neural network model able to anticipate the variation would probably be suited.

In the absence of such a model,

- An equalization tank would be useful
- A primary settler could play this role with the additional advantage of reducing the SS at the inlet of the bioreactor.
- Most of the non volatile SS could be removed thus preventing their accumulation in the aerated tank .

For instance

- For a SRT of 15 days
- a HRT of 4 hours
- A biomass concentration of 10 g/l
- The removal of 50 mg/l of non volatile solids will result in a decrease of 40% of the sludge concentration.

Is a more efficient pretreatment needed?

- Preflocculation and settling decreases dramaticaly the SS and the organic load.
- Advantages:
- Smaller aerated tank
- Smaller sludge concentration
- Faster biodegradation
- Elimination of most of the potential fouling agents in the feed.
- Phosphorus Removal

• Drawbacks:

- Production of inorganic (chemical) sludge.
- Control of phosphorus needed.
- The decrease in membrane area may be not sufficient for balancing the additional investment and operational cost.

Other Idea?

- Addition of PAC
- for adsorption of organics present in the supernatant
- And thus stressing the biomass for minimizing the yeld
- In addition less fouling of the membrane
- Continuous addition and withdrawal .
- Advantage : PAC is more efficient
- Disadvantage : cost and sludge production.

- Periodic addition and withdrawal : bioregeneration of PAC?
- Advantage : minimization of PAC use , sludge production and cost

• Drawback : efficiency?

Other idea?

- Supported biomass + membrane separation
- The advantages of supported biomass :
 - More resistant to feed variation
 - Less fouling ?
- But due to membrane separation, suspended cells are retained and accumulated in the reactor.
- See the papers of Tor Ove LEIKNES (NTNU)

A new idea

- COD and nitrogen removal_by biofilms growing on gas permeable_membranes
- Michael J. Semmens_, _, Karl Dahm, John Shanahan and Alina Christianson



Sapporo COE course July 2004

А

В



Results

- N removal rates as high as 1 Kg/m3-day or 2 g/m2-day were obtained while the corresponding COD removal rates were 4.5 Kg/m3-day or 10 g/m2-day.
- No result concerning phosphorus removal
- Difficulty in controlling the biomass growth

MBR

For Nutrient Removal

Nutrient Removal

- Is one of the present targets of waste water treatment in most developed countries.
- Nitrification/ denitrification has already be put in operation at large scale in conventional activated sludge processes as in MBR
- Less experience on P bio-removal

NUTRIENT REMOVAL

- Occurs naturally by the discharge of excess sludge (C/N/P : 100/5/1) and is thus dependent of the sludge age.
- Higher the sludge age, lower the excess sludge production ,higher the organics removal ,lower the nutrient removal by the bio-production.
- However different mechanisms for N and P.

Nitrification

- Is dependent on the growth of a population of nitrifying bacteria
- This occurs when the sludge age (SRT) is greater than 5 days.
- Higher the sludge age , higher the efficiency of nitrification
- MBR are very efficient in nitrification

MBR with Nit. Denit.

- MBR is naturally suited for Nitrification (large SRT)
- Denitrification can be easily obtained in an anoxic tank upstream of the aerated tank
- Or eventually in the same aerated tank with intermittent aeration

Nutrient Removal - N





Denitrification

- Needs the growth of a population of denitrifying bacteria.
- This occurs in anoxic conditions with the simultaneous presence of Nitrates and organics in adequate concentrations.
- Generally obtained by recirculating the treated water in an anoxic tank upstream of the aerated tank.

The aerated tank

- Can be designed with periodic anoxic zone
- Even with submerged membranes needing a permanent bubbling .

Some recent studies

Removal of N and C by a porous carrier—membrane hybrid process+-Byong-Hee Jun<u>a</u>, Kazuhiko Miyanaga<u>b</u>, Yasunori Tanji<u>b</u> and Hajime Unno_ ,

• Using supported biomass for enhancing nitrification/denitrification in the biofilm

Supported biomass +membrane

 A porous carrier-membrane hybrid process was found to have improved nitrogen removal efficiency, due to stimulated denitrification as well as nitrification. The hybrid system achieved a 30% higher nitrogen removal ratio than that in the fluidized porous carrier system.

Conclusion

- Hybridizing a fluidized porous CS with a membrane system (HS) was studied.
- The intracarrier denitrification rate was twice as fast
- The nitrogen removal was not solely due to microbial nitrification/denitrification but also assimilation derived from microbial growth.
- The HS examined in the present study will be effective for the improved treatment of wastewater.

Membrane Sequencing Batch reactor

• Attempts for N and P removal

Membrane sequencing batch reactor system for the treatment of dairy wastewater Tae-Hyun Bae, Sung-Soo Han and Tae-Moon Tak-- SNU

- subcritical flux operation, and intermittent suction method
- the system could be operated for more than 110 days with only one membrane washing
- BOD removal 97–98%.
- SS-free effluent
- nitrogen removal rate reached 96%.
- Phosphorus removal reached 80% after system optimization

MSBR 2



MSBR 3



Sapporo COE course July 2004



The difficulties of P bio-removal



P increase during aeration period



Sapporo COE course July 2004

Conclusions MSBR

- Suited for dairy industry effluent
- Subcritical flux operation and intermittent suction
- High BOD removal
- High N removal
- P removal up to 80% in optimized conditions

Enhanced biological P and N removal using a sequencing anoxic/anaerobic membrane bioreactor_ (SAM) process Kyu-Hong Ahn^a, Kyung-Guen Song^a, -, Eulsaeng Cho^a, Jinwoo Cho^a, Hojoon Yun^a, Seockheon Lee^a and Jaeyoung

Kim<u>b</u>

KIST and SNU

SAM Process : conditions of operation and results

- Filtrate flux : 10 L/m2/h (30 L/d)..
- The phosphorous removal was good 93%. By supplying strict anaerobic conditions without an internal recycle, the phosphorus release was reduced in a significant amount, resulting in excellent uptake of phosphorus in the aerobic zone.
- The nitrogen removal efficiency of the SAM was poor about 60

Coupling Physico-chemical removal of P with biological removal of N

- Fe and Al salts are very effective for the removing of P as phosphates which precipitate and are removed with the excess sludge.
- For domestic effluents the additional sludge production is small and the Fe concentration in the treated water and in the sludge is small too.

Hydrodynamic control of membrane operation

How to minimize the fouling with small energy consumption?



Figure 5. Effect of air flow rate on the Rt/Rm ratio at different activated sludge concentration.

Pilot's P&ID



Fouling Curves



Permeate Flux (I/h.m²)

Fouling Rate Determination



Continuous Aeration Configuration



Evolution of the Fouling Rate with the Air Flow in Continuous Aeration



Evolution of the Fouling Rate with the Cycling Frequency



Advantages of Cyclic Aeration

• Unsteady State Generation

- Higher local aeration intensity, bigger bubbles
- Reduction of bubble by-pass between fiber bundles
- Increased contact between fibers and bubbles

• Density Gradients

- Lateral liquid flow through the fiber bundle
- Increased fiber movement

Influence of Cycling for the Treatment of Municipal Wastewater



Some economic considerations

Product Cost curve



Wastewater: Cassette Size



Replacement cost in Euros/M³ (Membrane life :50 000 Hours)

	10	50 L/M2.h	100 L/M2.h
	L/M2.h		
40	0.08	0.016	0.008
Euros/M2			
80	0.16	0.032	0.016
Euros/M2			
100 Euros	0.2	0.04	0.02

Energy cost in membrane operation

- 1KWH = 0.05 Euro
- Cross Flow ...1 3 KWh/M3 ... 0.05 0.15 E/M3
- Bubbling ...0.1 0.3 KWh/M3 ... 0.005 0.015 E/M3
- Aeration ... 0.3 0.6 Kwh/M3 .. 0.015 0.03 E/M3

Wastewater: Energy Consumption



Wastewater: Cost





Municipal Market Growth

MF/UF/NF Worldwide Installed Capacities

