Influence of Membrane Flux on the Performance of a Pilot-Scale Membrane Bioreactor Treating Low C/N Wastewater

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To comply with current and anticipated water-quality regulations, membrane technologies have been adopted widely around the world. In particular, low-pressure membrane bioreactors (MBRs), including microfiltration or ultrafiltration, have attracted considerable attention for water and wastewater treatment to remove particulate and colloidal matter.

The advantages of MBRs over conventional treatment include a smaller footprint and less sludge production. Moreover, MBRs produce superior effluent quality to conventional tertiary treatment, capable of meeting more stringent future discharge limits and wastewater reclamation goals.

One of the major disadvantages of the MBR is membrane fouling, which occurs rapidly when the flux rate exceeds a certain "critical flux." Several factors can contribute to membrane fouling, namely operational parameters and sludge characteristics. For successful MBR operation, it is essential to quantify the effect of the wastewater characteristics on the performance of MBR at multiple flux rates in order to determine the "critical flux"; therefore, the main objective of this study was to determine the critical flux of a pilot-scale MBR treating real-time, low carbon/nitrogen (C/N) wastewater.

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Figure 1: Schematic diagram of the pilot-scale MBR setup (Systems A and B operated at 12 and 10 SRT, respectively)

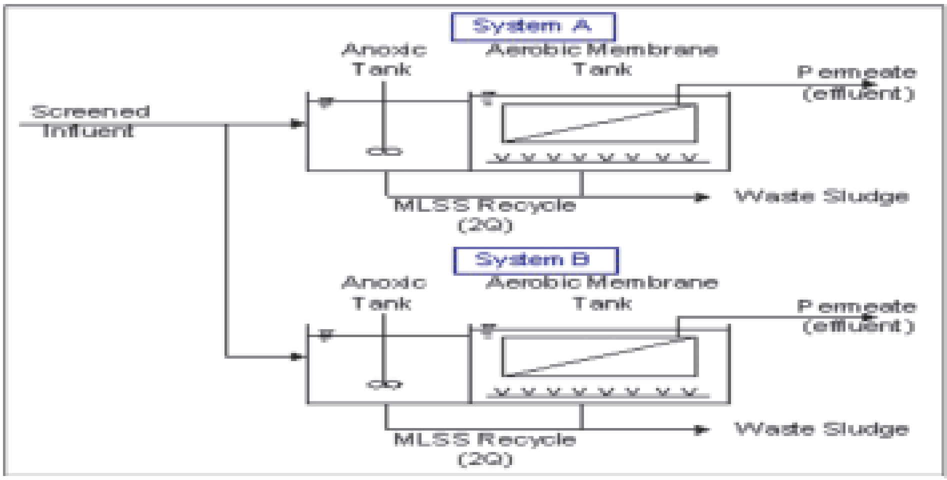

Table 1: Performance of the pilot-scale MBR in low C/N wastewater treatment

Flux (LMH)	SRT (d)	TSS			VSS			COD			BOD_5			NH_4^+-N		
		I	E	R	I	E	R	I	E	R	I	E	R	I	E	R
5.95	12	61	3	95	37	2	95	66	13	81	46	**7**	90	39	**3**	92
	10	61	3	95	37	3	93	66	13	81	46	**8**	87	39	**5**	91
7.14	12	58	10	83	30	6	80	70	10	85	50	**7**	87	45	**1**	98
	10	58	6	89	30	4	86	70	9	87	50	**6**	89	45	**1**	98
8.93	12	59	8	86	34	5	85	79	14	82	49	**4**	92	38	**2**	95
	10	59	6	90	34	3	91	79	14	82	49	**5**	89	38	**3**	93

* I, E and R represents influent (mg/L), effluent (mg/L) and removal (%), respectively

Materials & Methods

The MBR system includes anoxic and aerobic zones in one reactor. This system was operated for the effective removal of organic matter and ammonia nitrogen (NH_4^+-N) from a real-time, low C/N wastewater. The schematic diagram of the MBR system is shown in Figure 1.

The average flow to the reactor was 24 m^3/day and operated with a hydraulic retention time (HRT) of 1.92 hours. The membrane material was made of polypropylene with a normal pore size of 0.1-0.3 µm. The reactor was operated under two sludge retention times (SRTs)—12 and 10 days—with three different fluxes: 5.95, 7.14, and 8.93 liters per square meter per hour (LMH). The air flow rate was maintained at 0.48 m^3/min.

The wastewater flow into the reactor, flux control, pH adjustment, membrane cleaning and temperature monitoring were automated using control systems. The average total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), and NH_4^+-N concentrations in the influent were 60, 35, 75, 50 and 45 mg/L, respectively.

Results & Discussion

The influent characteristics of the wastewater and the MBR performance are shown in Table 1. As a result of MBR operation, TSS, VSS, COD, BOD_5 and NH_4^+-N were removed maximum by 95, 95, 87, 92, and 98 percent, respectively. Subsequently, filtration resistance was determined following the Darcy's law, shown as Equation 1, and the critical flux at 25°C was estimated using the empirical relationship shown as Equation 2.

$$J_T = \frac{\Delta P}{\mu R_t} \qquad (1)$$

$$J_{25} = J_T 1.025^{(25-T)} \qquad (2)$$

Where J is the permeate flux, **Δ**P is the transmembrane pressure (TMP), μ is the viscosity of permeate, and R_t is the total filtration resistance. The variation of TMP under various flux rates at 12 and 10 days SRT is shown in Figure 2. Also, the membrane fouling rates, average MLSS concentration, cycle time, and permeate per filtration area under different flux rates are shown in Table 2.

At the 10 days SRT, membrane fouling rates of 5.4×10^{11} and 5.7×10^{11} m/day were observed at 7.14 and 5.95 LMH flux rates, respectively. The membrane fouling rate increased substantially once the membrane flux increased to 8.93 LMH, indicating a critical flux rate between 7.14 and 8.93 LMH. A critical flux rate was similarly determined when the mixed liquor suspended solids (MLSS) concentration was increased to give 12 days SRT (data not shown). To avoid the rapid fouling of the membrane, the selected flux rate for design and operation should be lower than the critical flux.

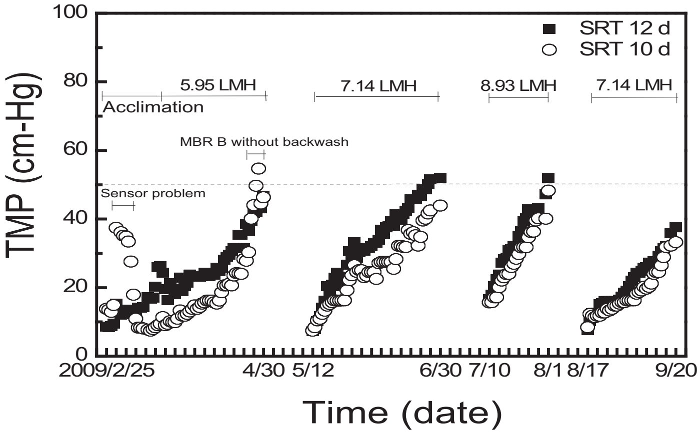

Figure 2: TMP profile under various flux rates at 12 and 10 days SRT

Table 2: MBR characteristics during operation under various flux rates and SRTs

Parameter	Various flux rates (LMH) under 12 days SRT				Various flux rates (LMH) at 10 days SRT			
	5.95	7.14	8.93	7.14*	5.95	7.14	8.93	7.14*
Fouling rate (10^{11}/m/d)	6.49	6.52	9.60	6.61	5.70	5.33	8.81	5.45
MLSS (mg/L)	5304	5145	7568	6101	3487	4436	4012	5031
Cycle time (days)	65	63	37	70	78	80	38	85
Permeate per filtration area (m^3/m^2)	9.44	10.13	7.03	10.70	11.38	12.86	7.34	13.10

* Experiment repeated at a flux rate of 7.14 LMH