© IWA Publishing 2018
589

Water Practice & Technology Vol 13 No 3
doi: 10.2166/wpt.2018.066

Performance of a full-scale ceramic MBR system to treat domestic sewage

T. Niwa[a,*], R. Yin[a], M. H. Oo[a], H. Noguchi[a], T. Watanabe[b], L. Y. Razali[c], H. Y. Png[c], W. C. L. Lay[c], K. A. Ong[c] and M. Alom[c]

[a] Meiden Singapore Pte Ltd, 5 Jalan Pesawat, Singapore 619363

[b] Meidensha Corporation, Meiko Building, 5-5-5 Osaki, Shinagawa-ku, Tokyo, 141-8616, Japan

[c] PUB, Singapore's National Water Agency, 40, Scotts Road, #15-01 Environment Building, Singapore 228231

*Corresponding author. E-mail: niwa.t@meidensg.com.sg

Abstract

Application of membrane technology for water reclamation has grown significantly in recent years due to reduced footprint size and more consistent product water quality. For a membrane bioreactor (MBR) system, it is critical for it to be robust to allow membrane systems to operate at higher flux without significant increase of trans-membrane pressure (TMP). A full-scale ceramic MBR system was installed at Changi Water Reclamation Plant (CWRP) as part of an MBR retrofit project to increase treatment capacity without expanding the plant's footprint. The nominal capacity of the ceramic MBR system is 15,000 m^3/d. The system has been successfully operating since January 2017 with a net flux of 30–60 L/m^2-hr (LMH). Stable operation was observed at nominal production capacity for more than 3 months. During that period, the TMP was stable in the range of 9–14 kPa for Tank A and 10–17 kPa for Tank B. Permeate turbidity was recorded in the range of 0.04–0.06 NTU for both Tank A and Tank B.

Key words: Ceramic MBR, flux, TMP, water reclamation

INTRODUCTION

Although there are reports of full-scale membrane bioreactor (MBR) systems using polymeric micro-filtration/ultrafiltration (MF/UF) membranes (Oo *et al.* 2007; Tao *et al.* 2009), investigation of full-scale ceramic MBR systems is limited. Ceramic MBR systems have been tested at smaller-scale during the past decade and the results show that performance is potentially better in terms of flux and system robustness. Use of a large-scale ceramic MBR system for treatment of industrial effluent was reported recently (Noguchi *et al.* 2016). As part of an MBR retrofit project at Changi Water Reclamation Plant (CWRP) in Singapore, ceramic flat sheet membranes were installed in the Membrane Plant 1.1 with a treatment capacity of 15,000 m^3/d, making it one of the world's largest ceramic MBR installations. The MBR retrofit approach presented a more cost-effective option with shorter construction time to achieve the required capacity compared to building an entirely new treatment facility. The objective of this study is to gain more experience in operation and maintenance of a ceramic MBR in a large-scale plant that treats domestic sewage.

SYSTEM INFORMATION

The ceramic membrane system at CWRP consists of two membrane tanks with a volume of 683 m^3 per tank. The ceramic membrane system is part of an MBR system that includes an anoxic tank and an aerobic tank with a relatively short hydraulic retention time (HRT) of approximately 3 hours for a

Water Practice & Technology Vol 13 No 3
doi: 10.2166/wpt.2018.066

flow of 15,000 m^3/d. Figure 1 shows pictures of the membrane tank and the membrane unit. For normal operation, the production capacity of the ceramic MBR system is set at 15,000 m^3/d, with a net flux of 30 L/m^2-hr (LMH). There are 2 trains of ceramic membranes which each have a capacity of 7,500 m^3/d. Maintenance cleaning (MC) is conducted twice per week with sodium hypochlorite (NaClO). The operating cycle is set at 14.5 minutes of filtration and 0.5 minute of backwash.

Figure 1 | Picture of the membrane tank (left) and the membrane unit (right).

RESULTS AND DISCUSSION

Initial results showed that ceramic MBR operation is sustainable at various production capacities with regular MC. While operating at a nominal production of 15,000 m^3/d, respective permeability remains stable above 340 and 300 LMH/bar for Tank A and Tank B with a MC frequency of twice per week. Although online operating data from 24 April to 28 June was captured and presented here, operating data earlier than 24 April was unfortunately lost during an update of the control system.

Trend of TMP and permeate flow

Figure 2 shows the trend of TMP and permeate flow of Tank A. The operating range of TMP was found to be 9–14 kPa, while production was maintained at approximately 360 m^3/h. When one of the MBR trains

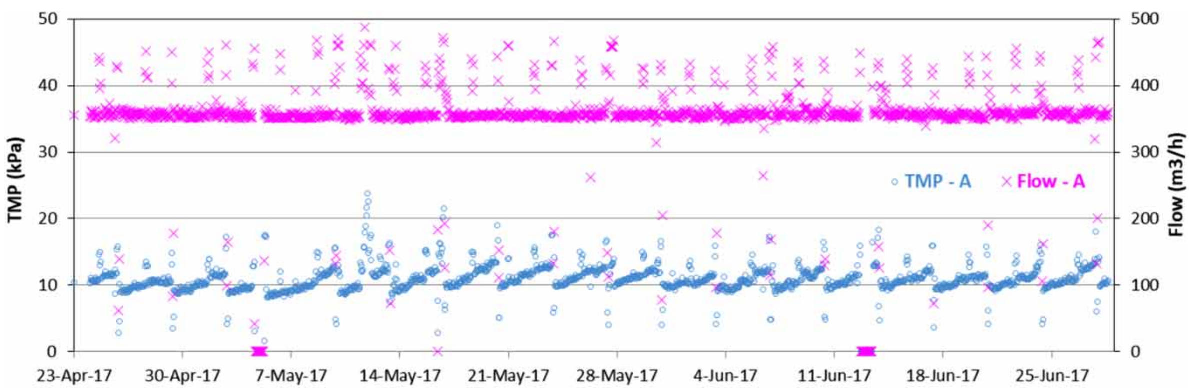

Figure 2 | Trend of TMP and permeate flow of Tank A.

Water Practice & Technology Vol 13 No 3
doi: 10.2166/wpt.2018.066

stopped for MC, production capacity was ramped up to 420–450 m^3/h and TMP increased accordingly. Baseline TMP after respective MC was found to be relatively stable at less than 10 kPa for Tank A.

Figure 3 shows the trend of TMP and permeate flow of Tank B. The operating range of TMP varied between 10–17 kPa, while permeate flow rate was maintained at the same level as that of Tank A at 360 m^3/h. Similar to Tank A, TMP spikes in Tank B appear when there is a need for MC at one of the other MBR trains. Respective permeate flow rate during the MC of the other train was found to be 420–450 m^3/h. Baseline TMP of Tank B after respective MC seems to be stable at less than 12 kPa.

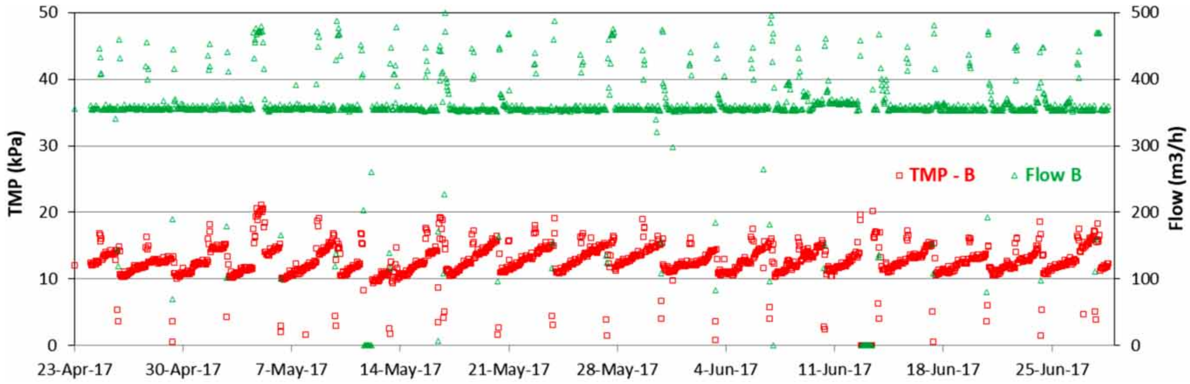

Figure 3 | Trend of TMP and permeate flow of Tank B.

Trend of permeability

Figure 4 shows the permeability index of Tank A from April to June 2017. The permeability index here represents the value after respective MC or recovery cleaning (RC). For that period, the permeability index varied in the range of 0.81–0.92. A highest index of 1.0 was observed after RC was conducted on 5 May 2017. The rate of permeability decline after RC seems to be insignificant. Instead of a continuous decline of the permeability index at the end of subsequent MC, recovery of permeability was observed after a certain cycle of MC. This could be due to favorable and stable sludge characteristics and maintaining better water quality at the end of those MC cycles.

Figure 5 shows the permeability index of Tank B from April to June 2017. For that period, the permeability index varied in the range of 0.82–0.93. A highest index of 1.0 was observed after RC was conducted on 11 May 2017. Rate of permeability decline after RC seems to be almost negligible and the permeability index recovered during June from an earlier decline towards the end of May. The permeability indexes are compared at a similar permeate flow rate to avoid/minimize the impact of flow variations. The impact of temperature on the permeability index however was not looked at in this study.

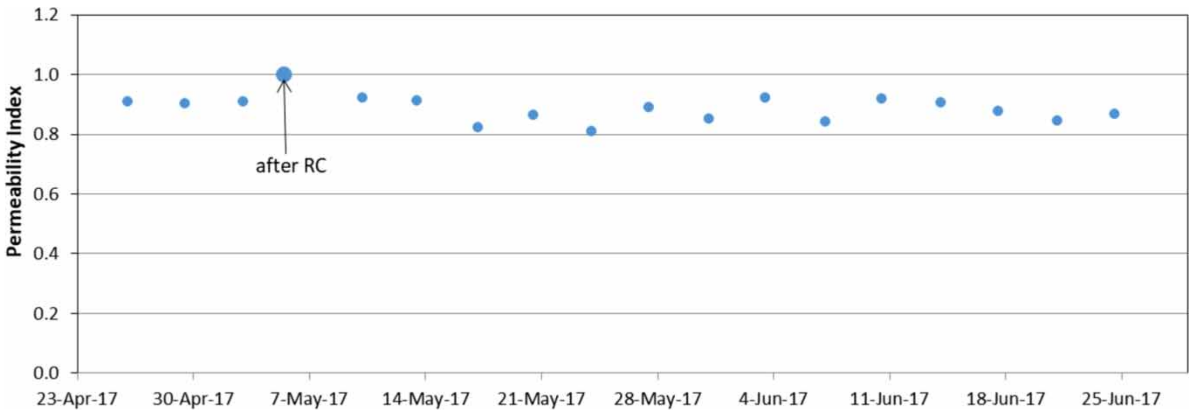

Figure 4 | Trend of permeability index in Tank A.

Water Practice & Technology Vol 13 No 3
doi: 10.2166/wpt.2018.066

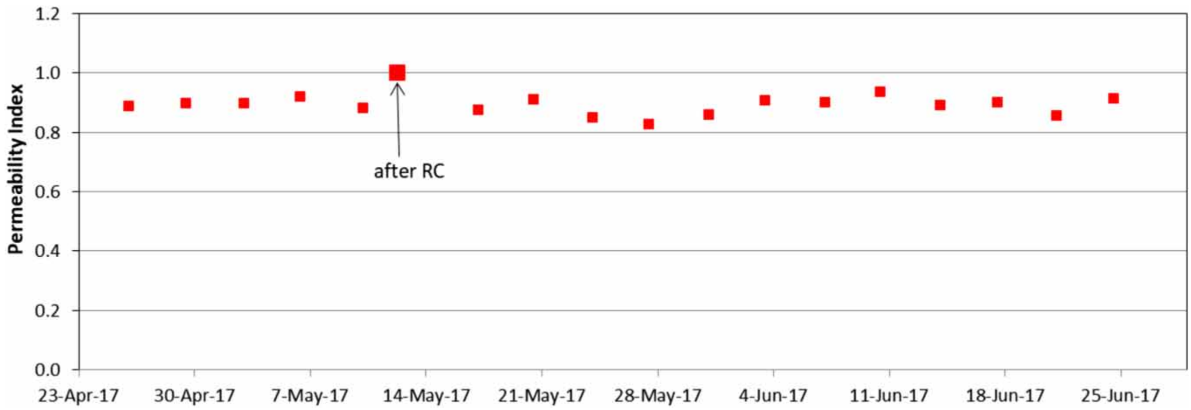

Figure 5 | Trend of permeability index in Tank B.

Table 1 | Range of sludge characteristics from March to June 2017

	Membrane Tank MLSS (mg/L)		RAS		
	Tank A	Tank B	MLSS (mg/L)	TTF (sec)	SV_{30} (mL/500 mL)
Min	3,420	3,630	3,740	72	360
Max	5,540	5,830	6,650	102	470
Avg.	4,396	4,469	5,110	87	420
Medium	4,300	4,369	4,900	86	420
90%ile	5,101	5,077	6,095	100	458

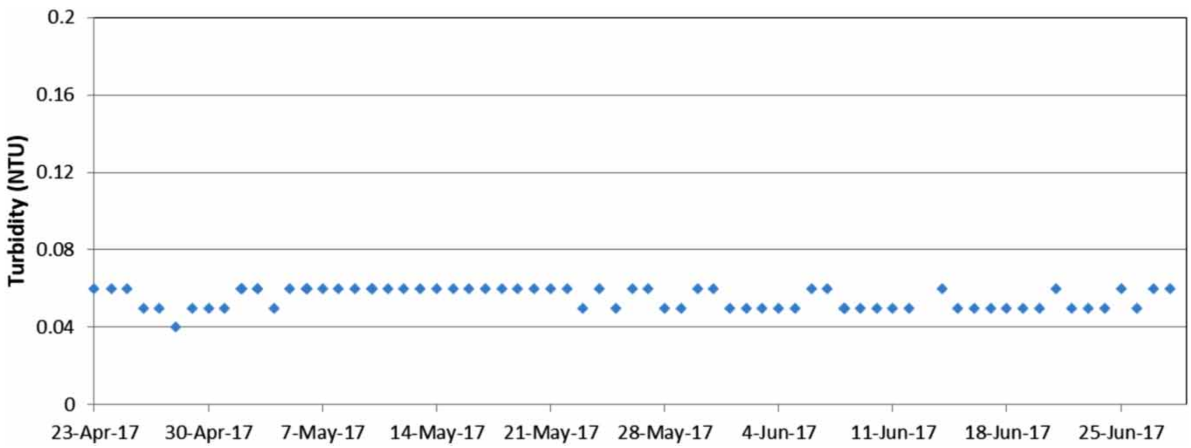

Figure 6 | Permeate turbidity in Tank A.

Sludge characteristics and permeate turbidity

Table 1 shows the sludge quality with respective operating range during March–June 2017. Average mixed liquor suspended solids (MLSS) in Tank A and Tank B were 4,396 mg/L and 4,496 mg/L respectively, while MLSS in the return activated sludge (RAS) stream was 5,110 mg/L. During that period, time to filter (TTF) was found to be in the range of 72–102 sec, with a 90 percentile TTF of 100 sec. During the same period, sludge volume after 30 minutes of settling (SV_{30}) was recorded to be 360–470 mL/500 mL, with an average SV_{30} standing at 420 mL/500 mL. During the same period, solids retention time (SRT) of the MBR system was maintained at 10 days. Permeate turbidity

Water Practice & Technology Vol 13 No 3
doi: 10.2166/wpt.2018.066

of both Tank A and Tank B remained consistently stable at 0.04–0.06 NTU. Figure 6 shows the trend of permeate turbidity for Tank A.

CONCLUSION

A full-scale ceramic MBR system was installed and operated at CWRP as part of an MBR retrofit project. The nominal capacity of the ceramic MBR system is 15,000 m^3/d. The system has been successfully operating since January 2017 with possibility to operate at a net flux of 30–60 LMH. Stable operation was observed at normal production capacity for more than 3 months in addition to an initial 2–3 months of operation at various production capacities during plant trialling and optimisation. When the ceramic MBR system was operating at 15,000 m^3/d, TMP was stable in the range of 9–14 kPa and 10–17 kPa for Tank A and Tank B, respectively. When either one of the ceramic or polymeric membrane trains is stopped for MC, production rate of other trains is ramped up to maintain the overall production capacity of the plant. The respective permeability index of Tank A and Tank B are similar and are in the range of 0.81–0.92 and 0.92–0.93, respectively. Permeate turbidity was maintained in the range of 0.04–0.06 NTU.

REFERENCES

Noguchi, H., Niwa, T., Yamashita, T., Shiota, H., Ang, W. S. & Kekre, K. 2016 Treatment of industrial used water by UASB + CMBR process to produce industrial grade water for reuse. *Water Practice and Technology* **13**(2), 424–430.

Oo, M. H., Kekre, K., Tao, G., Qin, J. J. & Seah, H. 2007 Membrane bioreactor for water reuse in Singapore. In: *Proceedings of the International Membrane Science and Technology Conference 2007*, November 5–9, Sydney, Australia.

Tao, G., Kekre, K., Oo, M. H., Viswanath, B., Lew, C. H., Kan, L. M. & Seah, H. 2009 Large scale membrane bioreactor plant design (retrofit) and optimization. Presented at the *IWA Membrane Technology Conference and Exhibition*, September 1–3, Beijing, China.