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Peak flux performance and microbial removal by selected membrane bioreactor systems

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ABSTRACT

A pilot study was conducted over a period of 18 months at the Point Loma Wastewater Treatment Plant (PLWWTP) in San Diego, CA to evaluate the operational and water quality performance of six selected membrane bioreactor (MBR) systems at average and peak flux operation. Each of these systems was operated at peak flux for 4 h a day for six consecutive days to assess peak flux performance. Virus seeding studies were also conducted during peak flux operation to assess the capability of these systems to reject MS-2 coliphage. When operating at steady state, these MBR systems achieved an effluent BOD concentration of <2 mg/L and a turbidity of <0.1 NTU. Peak flux for the MBR systems ranged from 56 to 76 L/m^2/h (liters per square meter per hour) with peaking factors in the range of 1.5–3.2. When switching from average to peak flux operation, a reversible drop of 22–32% in temperature-corrected permeability was observed for all submerged MBR systems. The percent drop in permeability increased as MLSS concentration in the membrane tank increased from 11,100 mg/L to 15,300 mg/L and was observed to be highest for the system operating at highest MLSS concentration. Such trends were not observed with an external MBR system. Each MBR system was able to sustain a 4-h-a-day peak flow for six consecutive days with only moderate membrane fouling. The membrane fouling was quantified by measuring the drop in temperature-corrected permeability. This drop ranged from 13 to 33% over six days for different submerged MBR systems. The MBR systems achieved microbial removal in the range of 5.8–6.9 logs for total coliform bacteria, >5.5 to >6.0 logs for fecal coliform bacteria and 2.6 to >3.4 logs for indigenous MS-2 coliphages. When operating at peak flux, seeded MS-2 coliphage removal ranged from 1.0 to 4.4 logs, respectively. The higher log removal values (LRVs) for indigenous MS-2 coliphage among different MBR systems were probably the result of particle association of indigenous coliphage. Differences in membrane pore size (0.04–0.2 μm) amongst the MBR systems evaluated did not have a substantial impact on indigenous MS-2 coliphage removal, but seeded MS-2 coliphage removal varied among the different MBR systems.

1. Introduction

With increasing global water demand, water reclamation is becoming essential for the sustainability of water resources. Membrane bioreactor (MBR) is a rapidly growing technology for municipal wastewater treatment since it offers several advantages over a conventional activated sludge process. These advantages include a smaller footprint, a consistent,

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high quality effluent irrespective of sludge settling characteristics, a low sludge production at high solids retention time (SRT) and a high quality effluent suitable for reverse osmosis (RO) feed streams (MWH, 2004). The global MBR market is estimated at United States dollar (USD) 216.6 million and while growing at a rate of 10.9%; it is estimated to approach USD 363 million in 2010 (BCC Research, 2006). The competition resulting from influx of new vendors, accompanied by recent advances in technology, helped decrease membrane costs by 33% during the period of 2000–2006 (DeCarolis et al., 2008). MBR products that have recently entered the U.S. market include Puron® from Koch Membrane Systems, Huber VRM® Bioreactor from Huber Technologies, Neosep™ from Kruger Inc., DynaLift™ from Parkson Corporation and Aria™/Microza (MUNC-620A and MUDC-620A) from Pall Corporation.

One of the key challenges for full-scale MBR installations is to handle diurnal and wet weather peak flows. Since wastewater has to pass through the membrane to be considered treated, the ability of the membrane to operate at high fluxes without substantial fouling is of critical importance. Very few studies have documented the performance of MBR systems during peak flux or wet weather operation (Trussell et al., 2006; Grelot et al., 2009). Trussell et al. (2006) found that deflocculation of sludge during wet weather flows caused an increase in colloidal content in mixed liquor and resulted in severe membrane fouling. While modeling for peak wet weather flow, Giraldo and LeChevallier (2007) observed that a low peak flux of long duration can be a more challenging condition to the membrane system than a high peak flux of short duration.

Conventional wastewater treatment consisting of primary and secondary treatment can achieve 2.5–4.0 log removal of total coliform bacteria, 2.5–3.5 log removal of fecal coliform bacteria and 2.0–3.0 log removal of indigenous coliphages (Zhang and Farahbakhsh, 2007; Rose et al., 1996; Ueda and Horan, 2000; Koivunen et al., 2003). For disinfected tertiary effluent, California Title 22 regulations require a minimum chlorine CT value of 450 mg-min/L or a 5-log virus inactivation in addition to the effluent total coliform concentration not exceeding a 7-day median of 2.2 most probable number (MPN)/100 mL (CDPH, 2001). If allowed by regulations, chlorination requirements for an MBR effluent could be significantly lower than those for conventionally-treated effluent since the former process produces high quality effluent with a very low microbial concentration (Mansell et al., 2007). Several studies have reported >5-log removal of total and fecal coliform bacteria by membrane filtration alone (without disinfection) by MBR systems (Ueda and Horan, 2000; Adham and DeCarolis, 2004; Mansell et al., 2004; Ottoson et al., 2006; Zhang and Farahbakhsh, 2007; Winward et al., 2008). Other studies have reported high removal of indigenous coliphages from wastewater through membrane filtration alone (without disinfection) by MBR systems (Adham and DeCarolis, 2004; Mansell et al., 2004; Zhang and Farahbakhsh, 2007). Some virus seeding studies have shown seeded virus removal by MBR systems to vary from 1.0-log to 5.9-log (Madaeni et al., 1995, Ueda and Horan, 2000).

There is a paucity of information available on fouling of the membranes during actual peak flux operation. Salient issues in relation to peak flux operation include the maximum flux under which the membrane can operate, membrane fouling rate, maximum duration and required operational changes. Also, few studies have documented comparative microbial removal by several different MBR systems at average and peak flux operation; especially with regards to both indigenous and seeded coliphage. Therefore, the objectives of this study were to evaluate six different MBR systems in relation to:

- Membrane performance at peak flux operation; and
- Water quality performance at average flux performance by measuring particulate, organic and microbial removal
- Seeded MS-2 coliphage removal at peak flux operation

2. Materials and methods

2.1. Feed water quality

The research study was conducted over a period of 18-months at the 760-MLD (million liters per day) Point Loma (San Diego, CA) Wastewater Treatment Plant (PLWWTP) that produces advanced primary effluent. The process consists of screening, grit removal, chemical coagulation (using ferric chloride and cationic polymer), primary clarification and effluent screening. During an earlier pilot study at this treatment plant, the coauthors did not observe any adverse effect of coagulant on MBR performance (DeCarolis and Adham, 2007). Feed to the pilot plants was collected from a screened (using bar-screen) raw wastewater channel just before the primary clarifiers. Screened wastewater containing 15–25 mg/L ferric chloride was further screened by a 0.8 mm Roto-Sieve rotating perforated drum screen (Model No. 4024-40). The MBR influent samples were collected after the raw wastewater was screened by the rotating drum screen.

Table 1 shows the feed water quality data during the pilot study. BOD_5 and TSS concentrations of MBR influent samples were lower than expected due to the fine screening and coagulant addition prior to the intake. The average BOD_5 concentration for the raw wastewater was measured at 252 mg/L (City of San Diego, 2005); after fine screening it was 162 mg/L,

Table 1 – Membrane bioreactor feed water quality during pilot study.

Parameter	Units	No. of analysis	Median ± Std. dev.
BOD	mg/L	151	155 ± 33
COD	mg/L	15	376 ± 47
TOC	mg/L	17	58 ± 18
Ammonia-N	mg/L-N	88	23.0 ± 3.3
Ortho-Phosphate	mg/L-P	18	0.076 ± 0.053
TSS	mg/L	251	178 ± 32
VSS	mg/L	148	137 ± 26
pH	–	136	7.1 ± 0.21
Turbidity	NTU	140	112 ± 23
Total coliform bacteria	CFU/100 mL	32	6.4E+07 ± 4.1E+07
Fecal coliform bacteria	CFU/100 mL	31	5.0E+06 ± 7.3E+06
Indigenous MS-2 coliphage	PFU/100 mL	28	2.3E+04 ± 1.4E+04