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Characterization of effluent water qualities from satellite membrane bioreactor facilities

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ABSTRACT

Membrane bioreactors (MBRs) are often a preferred treatment technology for satellite water recycling facilities since they produce consistent effluent water quality with a small footprint and require little or no supervision. While the water quality produced from centralized MBRs has been widely reported, there is no study in the literature addressing the effluent quality from a broad range of satellite facilities. Thus, a study was conducted to characterize effluent water qualities produced by satellite MBRs with respect to organic, inorganic, physical and microbial parameters. Results from sampling 38 satellite MBR facilities across the U.S. demonstrated that 90% of these facilities produced nitrified (NH_4-N <0.4 mg/L-N) effluents that have low organic carbon (TOC <8.1 mg/L), turbidities of <0.7 NTU, total coliform bacterial concentrations <100 CFU/100 mL and indigenous MS-2 bacteriophage concentrations <21 PFU/100 mL. Multiple sampling events from selected satellite facilities demonstrated process capability to consistently produce effluent with low concentrations of ammonia, TOC and turbidity. UV-254 transmittance values varied substantially during multiple sampling events indicating a need for attention in designing downstream UV disinfection systems. Although enteroviruses, rotaviruses and hepatitis A viruses (HAV) were absent in all samples, adenoviruses were detected in effluents of all nine MBR facilities sampled. The presence of *Giardia* cysts in filtrate samples of two of nine MBR facilities sampled demonstrated the need for an appropriate disinfection process at these facilities.

1. Introduction

Use of recycled water for non-potable applications has increased dramatically in the United States; recycled water is now used in many applications that include landscape irrigation, fire protection, toilet and urinal flushing, agricultural irrigation, cooling and air conditioning. Most of these applications require a small flow of water and since the points of application are usually disperse, it becomes cost prohibitive to install conveyance pipelines to transfer recycled water from a centralized water reclamation facility to these points of application. Satellite or decentralized treatment facilities allow treatment of wastewater for local reuse applications and minimize the cost of conveyance infrastructure (Metcalf and Eddy, 2007). Installation of satellite and decentralized facilities, as a viable water recycling solution, has been

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increasing because of their demonstrated reliability, minimal footprint, elimination of new recycled water distribution pipelines, and potential to postpone central treatment capital improvement projects (Davis, 2009).

Water recycling applications with unrestricted access require disinfected tertiary effluent since the effluent is oftentimes utilized for irrigation of green space with unrestricted public access. For many satellite applications, this treatment needs to occur in a small footprint due to site constraints; therefore, footprint minimization and higher effluent quality are usually key drivers for satellite facilities. In addition, most satellite facilities are not staffed for 24 h a day, so a high level of automation is usually desired (Crites and Tchobanoglous, 1998; Davis, 2009). Since MBRs can achieve higher effluent water quality in a much smaller footprint compared to conventional treatment processes and require little or no supervision, it is the most widely used process for satellite facilities.

Compared to centralized facilities, decentralized/satellite facilities are typically designed for small service areas such as golf courses, shopping centers, hotels and schools and may not be designed with equalization basins due to footprint constraints. Such conditions often result in a high variation in flow-rates and organic loading that can potentially impact effluent water quality. Further, as noted above, satellite facilities are staffed intermittently, and in some cases, operator supervision is not provided for several days. Therefore, issues with the treatment process can be potentially overlooked at these facilities. Although several studies have reported effluent water quality for pilot and centralized full-scale MBR facilities (van der Roest et al., 2002; Innocenti et al., 2002; Adham and DeCarolis, 2004; Qin et al., 2006; Hirani et al., 2010; Simmons and Xagoraraki, 2011; Hirani et al., 2012), such data have not been reported previously in the literature for satellite facilities. Further, enumerating the presence of traditional or emerging pathogens in effluents of satellite facilities is warranted; organisms of concern include poliovirus, coxsackievirus, echovirus, hepatitis A virus (HAV), rotavirus, norovirus, adenovirus, *Cryptosporidium* and *Giardia* (Gerba and Smith, 2005). Therefore, the objective of this study was to characterize effluent water quality produced from numerous satellite MBR facilities. The data provided are particularly important since most existing water reuse guidelines were established before development and implementation of MBRs at satellite installations.

2. Materials and methods

2.1. MBR facilities participating in the study

The MBR facilities sampled during the study utilized different process configurations (submerged and external), membrane geometries (hollow-fiber, flat-sheet and tubular), fouling control strategies (relaxation and backwash) and membranes of varying ages (1–10 years). More than 80% of the facilities sampled utilized submerged MBR configuration. Hollow-fiber ultrafiltration membranes were the most commonly utilized membrane systems among the facilities sampled (70% of total), followed by tubular membranes (microfiltration and ultrafiltration) and flat-sheet microfiltration membranes. Less than 20% of the facilities sampled utilized external MBR configuration with tubular microfiltration or ultrafiltration membranes. Polyvinylidene Fluoride (PVDF) was the most commonly utilized membrane material followed by chlorinated Polyethylene (PE). Majority (83%) of the facilities sampled utilized backwashing as a fouling control strategy whereas the remaining utilized relaxation. The MBR facilities sampled were spread across six different states in the U.S. and three different United States Environmental Protection Agency (USEPA) regions; flow-rates at these facilities ranged from 0.3 to 284 cubic meter per hour (m^3/h). The MBR facilities sampled during the study are listed with their assigned identifiers in Table 1; the first two letters represent the name of the state where the facility was located. MBR facilities sampled employed fine screening before wastewater was fed to the biological reactors. The membrane system suppliers require screening the raw wastewater with 1–3 mm fine screens in order to comply with the membrane performance warranty.

2.2. Initial screening of 38 satellite MBR facilities

An initial screening of satellite MBR facilities was conducted to characterize effluent water quality. A grab sample of MBR effluent was collected from a wide range of satellite facilities (38 MBR facilities across several states in the US) and analyzed for a range of inorganic, organic, physical and microbial parameters. Table 2 presents the water quality parameters targeted during the study, the analytical methods employed, and the associated detection limits.

The effluent water quality data obtained from the initial screening of the 38 satellite facilities was utilized to segregate these facilities into one of three different bins. The

Table 1 – –MBR facilities participating in the study.

Plant identifier	Design capacity (m^3/h)	Plant identifier	Design capacity (m^3/h)
MA-01	13.2	NJ-12	7.9
MA-02	2.5	NJ-13	22.1
MA-03	1.7	NJ-14	51.1
CT-01	3.2	NJ-15	NA
MA-04	39.4	NJ-16	NA
CT-02	2.8	NJ-17	0.5
CT-03	1.9	NJ-18	0.5
RI-01	13.4	NJ-19	0.3
NJ-01	3.5	NJ-20	0.2
NJ-02	2.5	NJ-21	0.5
NJ-03	11.0	NJ-22	0.3
NJ-04	1.1	NJ-23	0.3
NJ-05	4.6	NJ-24	0.3
NJ-06	2.8	CA-01	283.9
NJ-07	2.8	NY-01	NA
NJ-08	0.3	NY-02	4.6
NJ-09	0.3	NY-03	0.6
NJ-10	38.5	NY-04	2.2
NJ-11	2.1	NY-05	3.9

NA = Not Available.