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Considerations for Sludge Management in Advanced Primary Treatment Technologies

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Introduction

Advanced Primary Treatment (APT), which utilizes primary filters (PF) or microscreens (MS), has been increasingly adopted to enhance wastewater treatment. APT improves the capture and diversion of solids and particulate carbon upstream of the secondary treatment process. APT technologies can achieve higher removal rates of total suspended solids (TSS) and total chemical oxygen demand (tCOD) than primary clarifiers (PCs). As a result, APT can reduce the aeration demand in secondary processes and increase energy production from anaerobic digesters. Between 2021 and 2025, in a California Energy Commission funded project, 3 APT technologies were evaluated at the Linda County Water District's (Linda) Water Resources Recovery Facility (WRRF): full-scale Cloth Disk Primary Filter (CDPF, upto 1400 gpm), demonstration-scale Proteus Primary Filter (PF, up to 20 gpm), and full-scale MicroScreen (MS, up to 500 gpm). These systems (Figs. 1, 2, and 3) were operated in parallel with existing PC.

Results obtained over 10-36 months of operation showed improved removal rates for TSS and tCOD compared to PC, especially for the PF technologies (i.e., 40-50 % higher compared to PC). The removal rates, as summarized in Fig. 4 for over 200 sampling events, were as follows: the CDPF achieved 84% TSS and 56% tCOD removal; the Proteus PF achieved (operating at 2 gpm/ft²) 85% TSS and 55% tCOD removal; and the MS removed 62% TSS and 40% tCOD. While the treatment performance and energy benefits of APT technologies are well documented[1,2,3,4,5,6], impacts of APT backwash reject streams (APT sludge) on sludge handling systems (thickening and anaerobic digestion) are less studied. Although increased removal by PF provides significant intensification and energy benefits, it also generates more challenging sludge streams, characterized by higher backwash volumes with low solids concentrations. These impacts must be considered carefully in the design and operation of PF systems to avoid adverse effects on WRRF hydraulic capacity and sludge-handling processes.

This project mainly focuses on pretreatment, thickening, and digestion challenges associated with high-volume, low-solids PF sludge. The primary objective is to define design and operational parameters that preserve the energy and intensification benefits of PF, while minimizing adverse impacts on sludge management. Knowledge gaps in the design and operation of sludge-handling systems for APT systems are identified and discussed in this paper.

Methods and Results

Sludge from APT systems were evaluated for: (1) filtered and sludge volumes and flows, (2) PF backwash reject ratio (BRR), and (3) PF sludge total solids (TS) concentration across varying hydraulic loading rates (HLR) and solids loading rates (SLR).

For CDPF, BRR increased with both HLR and SLR. As shown in Figure 5(A), the average daily BRR was 3.3% at an HLR of 0.20 gpm/ft² and increased to 11.5% at 1.65 gpm/ft², with an average of 5.5% over 3 years of operation. Similarly, as shown in Figure 5(B), the BRR increased from 3.4% at SLRs of 0.50–1.0 lb/day/ft² to 14.6% at an SLR of 11.0 lb/day/ft².

For Proteus PF, BRR also increased with HLR and SLR. As illustrated in Figure 6(A), average BRR ranged from 6.9% to 9.7% over an HLR range of 2–9.5 gpm/ft², peaking near the design HLR of 10 gpm/ft². BRR values between 8.2 and 10.3% as SLR increased from 0.7 to 8.6 lb/day/ft² as shown in Figure 6(B).

The MS system's performance was evaluated for sludge generation. Figure 7(A) shows that the BRR increased with higher HLR. At low-flow conditions (1.8-3.6 gpm/ft²), the BRR was between 0.7% and 2.0%. In contrast, at higher HLRs (5.8-9.2 gpm/ft²), the average BRR increased to 3.2%. Figure 7(B) illustrates that the BRR also increased with higher SLR. The average BRRs at SLRs of 7.6, 9.5, and 12.4 lbs/day/ft² were 1.7%, 2.0%, and 2.6%, respectively.

TS concentrations were also evaluated in the APT reject sludge flow to determine APT's sludge management requirements. The TS value in the backwash stream from the PF system was 0.2%, whereas a TS value of approximately 2% was observed for the backwash (sludge) reject from the MS technology.

Conclusions

The impact of different BRRs is a very important consideration in treatment plant design and operation. For example, for a 100 MGD WRRF, different BRRs result in markedly different thickening requirements. A 2% BRR for the MS technology produces a primary sludge flow of 2 MGD, compared to 10 MGD sludge flow for PF with BRR of 10% and 14.6 MGD sludge flow for PF operating at peak HLRs (Figure 9). These PF sludge flow rates are significantly higher than those from PCs. High BRRs combined with low TS increase thickening demands, making MS systems generally more favorable for sludge management. However, PF systems provide greater treatment performance and overall WRRF energy efficiency; therefore, APT system selection and design should be tailored to project-specific conditions and requirements.

Specific thickening requirements associated with high BRR values and low TS concentrations are currently being assessed in another ongoing technology demonstration project at the Linda WRRF using the following three sludge thickening technologies: Volute Thickener, Suspended Air Flotation, and Biosolids Filtration Thickener. Specific operational and design criteria for the application of these thickening technologies for APT are evaluated

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