Performance Evaluation of Cloth Disk Primary Filtration to Increase Carbon Diversion Toward Net-Zero Water Resource Recovery Facilities

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Several new filter technologies have been developed that can be used to increase primary treatment performance. In primary filtration (PF), filter technology is used to replace primary sedimentation.

The principal focus of this article is the performance of the first full-scale PF project using a fine pore cloth disk primary filter (CDPF) to maximize the diversion of carbon for the production of energy and to reduce energy usage. Performance data from related pilot-scale CDPF systems are included for process verification.

The removal performance for total suspended solids (TSS) from the three CDPF installations varied from 83 to 85 percent, as compared to 55 to 60 percent typically achieved with primary sedimentation. The removal performance for five-day biochemical oxygen demand (BOD_5) from the three CDPF installations varied from 46 to 58 percent, as compared to 32 to 38 percent BOD_5 removal typically achieved with primary sedimentation. The full-scale CDPF results reported here are from several previous pilot and demonstration projects, as well as an ongoing research and demonstration project, conducted for the California Energy Commission (CEC), to demonstrate the potential energy savings that can be achieved through the implementation of CDPF.

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Significance of and Technologies for Primary Filtration

Significant benefits that can result from the implementation PF, based on the results of previous studies (Caliskaner et al., 2015, 2016, 2017, 2019, 2020, 2021; Franchi and Santoro, 2015; Paulsrud et al., 2014; Rusten and Odegaard, 2006), include:

1. Decreased electrical energy required for aeration (by approximately 15 to 30 percent) in secondary treatment because of reduced organic loading.
2. Increased gas energy production in the anaerobic digestion process (by 30 to 40 percent) resulting from the high organic energy content of the volatile suspended solids (VSS) removed and the increased volume of primary sludge sent to the anaerobic digesters.
3. Expanded secondary treatment capacity by reducing the organic loading upstream of the secondary process.
4. Reduction of footprint required for primary treatment by approximately 60 to 70 percent.
5. Reduced capital cost for primary and secondary treatment processes.

Although there are several technologies used to replace primary sedimentation facilities, it's important to note that there are significant differences in the effluent quality, especially with respect to TSS concentration and particle size distribution. For example, there is no comparison between the effluent quality from technologies with pore sizes varying from 150 to 1,000 millimeters (mm)

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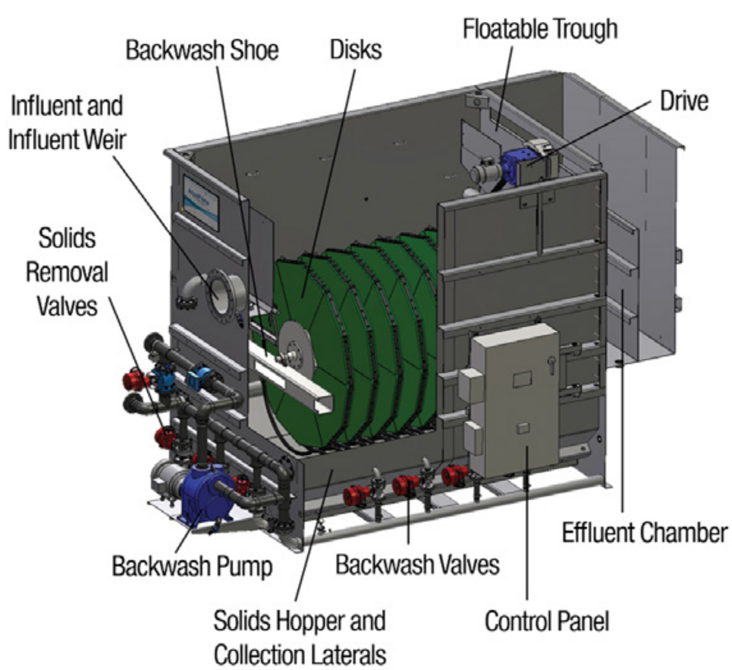

Figure 1. Demonstration of cloth disk primary filter installation.

Figure 2. Primary filtration system at the Linda Wastewater Resource Recovery Facility in Olivehurst, Calif. Left photo shows the cloth disk primary filter tank and the photo at right shows the eight individual cloth disks in the filter tank, with a chain drive used to rotate filters during a backwash cycle.

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and the effluent from a CDPF with a nominal pore size of 5 to 10 mm.

Cloth Disk Primary Filter

With the enhanced removal of organic material achieved with the CDPF that has a small pore size, the amount of carbonaceous BOD_5 that must be treated in the biological treatment process is reduced, which, in turn, results in a reduction in the energy requirements for aeration. The additional organic solids removed with the CDPF also result in greater digester gas production.

A definition sketch for the CDPF used in this study is shown in Figure 1. As shown, a CDPF is submerged in a receiving tank. As wastewater enters the receiving tank, floatable materials (e.g., fats, oils, and grease that solidify at ambient temperatures) rise to the surface of the tank and heavy solids settle to the bottom. Floatable material is skimmed from the surface and settled solids are removed with suction headers. The flow of wastewater to be filtered is from the outside through the filter cloth to the inside of the filter cloth housing. The filtered effluent, collected in a header connected to one or more disks, is discharged to the effluent channel.

In effect, there are three active zones within the filter tank: scum zone, filtration zone, and solids settling zone. The filtration processes work effectively because only marginally and neutrally buoyant suspended solids particles are filtered, as both floatable and readily settable material is removed separately and does not pass through the filter media, thus avoiding the solidified grease and solids loading problems that have plagued other direct filtration systems.

Operationally, filterable solids that accumulate on the surface of the filter disks also serve as a secondary filter. As more filterable solids accumulate on the surface of the filter disks, the water level in the tank increases as the headloss through the filter cloth increases. When the liquid level rises to a predetermined setpoint (typically at 12 in.), a backwash cycle is initiated automatically. The filterable solids that accumulate on both sides of the disk filter are removed with a vacuum suction header, which is in contact with the filter cloth. The applied vacuum suction allows the filter fibers to extend into the backwash vacuum suction header, thereby permitting solids that have accumulated on and within the cloth filter to dislodge and be removed.

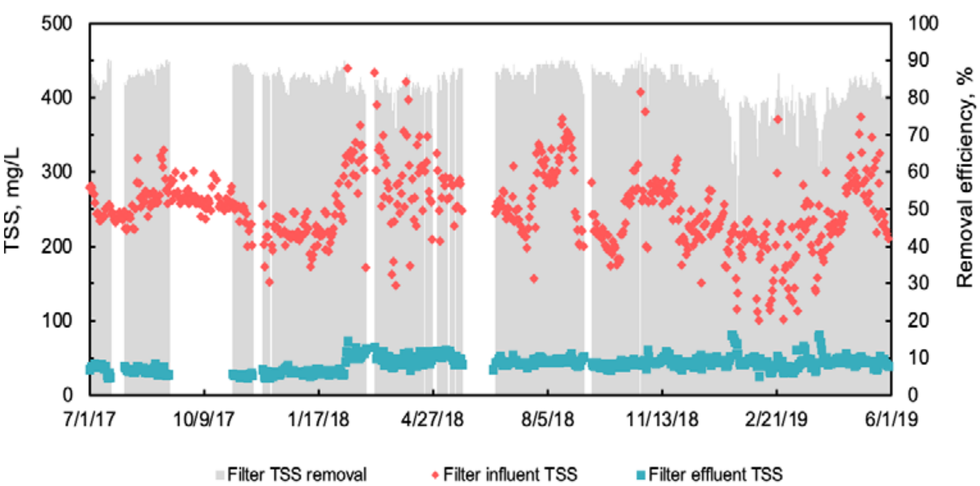

Figure 3. Average daily total suspended solids reductions for cloth disk primary filter installation at the Linda Wastewater Resource Recovery Facility based on total suspended solids/turbidity correlations. (Note that gaps in data during the reporting period reflect malfunctioning of the turbidimeter.)

First Full-Scale Primary Filter Installation at Linda Wastewater Resource Recovery Facility

The first full-scale CDPF system (Aqua-Aerobic Systems Inc., AquaPrime Filtration System) employing a fine pore cloth was installed at the Linda Wastewater Resource Recovery Facility (WRRF) located in Olivehurst, Calif. (Figure 2). Since startup in July 2017, the CDPF system has treated screened wastewater upstream of the secondary treatment process. Operation details of the CDPF system, monitoring and sampling procedures, and the approach used to assess the treatment and hydraulic performances of the CDPF system are discussed elsewhere (Caliskaner et al., 2020). Measured treatment performance data for the CDPF system are presented here to evaluate their impacts toward achieving net-zero WRRFs.

Treatment Performance

The treatment performance of the CDPF was evaluated in terms of removals achieved for TSS, BOD_5, chemical oxygen demand (COD), total kjeldahl nitrogen (TKN), and particle removal efficiency. Performance data from the full- and demonstration-scale CDPF installations were used to perform process simulations using BioWin 5.3. The simulations evaluated the impact of CDPF on downstream processes and energy benefits, including potential reduction in secondary treatment energy requirements and an increase in digester gas production. Results of the simulations are discussed further.

Total Suspended Solids Removal

The TSS removal data are presented in Table 1, based on laboratory measurements. Composite 24-hour samples were analyzed in the laboratory to assess the performance of the CDPF system for TSS removal. Influent TSS values ranged from 160 to 560 mg/L, with an average of 301 mg/L. The average removal performance for TSS was observed to be 83 percent (Table 1). The high TSS removal efficiency achieved by PF increases the volume of primary sludge sent to the anaerobic digesters, as compared to the primary sedimentation facilities. The daily variation in TSS removal over the duration of the test period is shown in Figure 3.

Process simulations using BioWin found that the CDPF resulted in a total sludge increase and biogas energy production increase of approximately 30 and 40 percent, respectively (Caliskaner et al., 2019). Reducing the amount of organic matter applied to the biological treatment process reduces the amount of carbon lost to the atmosphere during aerobic treatment (e.g., activated sludge) and the amount of waste sludge that must be processed. Thus, the total sludge that must be processed contains a much higher proportion of primary sludge, which is easier to digest and yields more gas, as opposed to waste activated sludge (Bolzonella et al., 2005).

Table 1. Concentration Ranges and Average Removal Performances for Key Constituents for the Cloth Disk Primary Filter Installed at the Linda Wastewater Resource Recovery Facility (a,b,c)

Constituent	Constituent concentrations, mg/L				Average removal, %
	Filter influent		Filter effluent		
	Range	Average	Range	Average	
TSS	160 - 560	301	24 - 89	48	83
COD	300 - 990	605	110 - 600	254	57
BOD_5	180 - 510	305	68 - 190	123	58
TKN	32 - 58	48	24 - 47	39	19

[a]Data for the period from 7/2017 through 6/2019
[b]Based on laboratory analyses of composite samples taken over 24 hours
[c]Adapted from Caliskaner et al., 2019

Table 2. Treatment Performance Summary of Cloth Disk Primary Filtration From Different Projects in the United States

Project Location	Size	Manufacturer	Average Removal, %		
			BOD_5	TSS	COD
Linda, CA	Full-Scale	Aqua-Aerobics	60	82	57
Lancaster, CA	Demonstration-Scale	Aqua-Aerobics	52	83	55
Manteca, CA	Demonstration-Scale	Aqua-Aerobics	50	83	47
Sand Island, HI	Demonstration-Scale	Aqua-Aerobics	53	78	54
Village Creek, TX	Demonstration-Scale	Aqua-Aerobics	60	88	64
San Francisco, CA	Demonstration-Scale	Aqua-Aerobics	46	80	43
Wailua, Kaua'I, HI	Demonstration-Scale	Aqua-Aerobics	50	86	43

An important observation to be made from the data presented in Figure 3 is that, regardless of the influent variability, the TSS effluent concentration was very stable. This stability is important with respect to the performance of the biological treatment process and for the corresponding reduction in the energy requirements for treatment, as peak loadings are reduced.

Biochemical Oxygen Demand and Chemical Oxygen Demand

Treatment performance for BOD_5 and COD is summarized In Table 1. Average removal efficiencies for BOD_5 and COD were 58 and 57 percent, respectively, which are considerably higher as compared to conventional primary sedimentation. Due to the significant organic load reduction upstream of the activated sludge process, the capacity of the secondary treatment processes was estimated to increase by approximately 20 percent. Further, by eliminating sudden peak solids and organic loadings to the activated sludge process, the stability of the secondary process is enhanced, leading to improved effluent quality and lower energy costs.

Total Kjeldahl Nitrogen Removal

As presented in Table 1, average TKN removal efficiency was observed to be 19 percent. Essentially, all of the TKN removal is associated with the removal of particulate solids.

Discussion of Full-Scale Primary Filtration System Performance

The primary goals of the CDPF

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technology development and demonstration project are to demonstrate long-term treatment performance and mechanical reliability, and to verify the process design and operational parameters for CDPF installations.

The CDPF process performance is compared to conventional primary sedimentation in the following section.

Treatment Performance

With respect to treatment, the following performance was achieved:

- TSS removal performance of CDPF was approximately 30 to 50 percent higher compared to conventional primary sedimentation.
- BOD_5 and COD removal with CDPF was approximately 30 to 50 percent higher compared to conventional primary sedimentation.
- The resulting increase in biogas energy production has been estimated to be between 30 and 40 percent, based on BioWin simulations using treatment performance results from full- and pilot-scale CDPF demonstrations (Caliskaner et al., 2019).
- Aeration power requirement in the downstream aerated activated sludge process is estimated to decrease by approximately 15 to 30 percent, depending on specific WRRF operating conditions. The corresponding capacity increase in secondary treatment processes is approximately 15 to 20 percent (Caliskaner et al., 2019).
- With CDPF, the footprint requirement is reduced by approximately 60 to 70 percent as compared to conventional primary clarifiers.

One of the big differences between the effluent from a CDPF installation and conventional primary sedimentation is that, regardless of the influent TSS loading, the effluent TSS concentration from the CDPF remained relatively constant (see Figure 3), as does the particle size distribution to be processed in the biological treatment process.

Verification of Cloth Disk Primary Filter Performance

To verify performance parameters for the CDPF technology, the results obtained from the full-scale CDPF system at Linda WRRF are compared with other demonstration projects, conducted at several demonstration sites across the United States (Table 2).

As seen in Table 2, CDPF removal performance was observed to be consistent from various pilot-, demonstration-, and full-scale projects.

Ongoing Technology Development and Demonstration Project

A three-and-a-half-year (2021-2025) technology research and demonstration project is underway at the WRRF to demonstrate the benefits and performance of three advanced primary technologies (APT) including CDPF, Microscreen, and compressible medium biofiltration, and three advanced secondary treatment (AST) technologies (membrane aerated bioreactor, aerobic granular sludge, and Microvi). The evaluation of the APT and AST systems is based on energy savings, capacity increase, and treatment performance.

To understand the impact of APT on secondary treatment and to have a comprehensive evaluation on the performance of the combined APT-AST configurations, four different process flow configurations are being demonstrated.

- Demonstration 1 is the baseline performance of primary clarifier combined with conventional secondary treatment.
- Demonstration 2 is to evaluate the treatment performance and economic benefits of enhanced secondary treatment downstream of APT technologies.
- Demonstration 3 is to evaluate the treatment performance of three AST technologies downstream of primary clarifier.
- Demonstration 4 is to evaluate a combined full-scale APT-AST system and quantify the benefits of advanced wastewater treatment.

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