Pilot-Scale Evaluation of Cloth Media Filtration Technology

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Introduction

The Sanitation Districts of Los Angeles County (Districts) operate 11 wastewater treatment facilities. Ten of these facilities are classified as water reclamation plants (WRPs) producing approximately 200 million gallons per day (MGD) of reclaimed water suitable for reuse. The Districts' Palmdale WRP treats approximately 10 MGD using primary treatment followed by stabilization ponds. This facility is currently undergoing design upgrades to tertiary treatment with biological nitrogen removal. The Districts initially planned to design and operate deep-bed mono-media (anthracite) gravity filters. However, due to potential capital and operating cost savings, cloth media filters (CMFs) were subsequently considered. While the Districts have extensive experience with the operation and performance of mono-media filters, CMFs are a relatively new technology without a long track record of successful operation. Based on preliminary information gathered by Districts' staff, potential performance issues were identified that could make this technology less attractive when compared to mono-media filters. One issue was the potential for matting of the CMFs with polymer used to enhance secondary clarifier performance. Polymer addition is typically employed at Districts' facilities and is planned for the Palmdale WRP. There is also a lack of well documented data on CMF effluent particle size distribution (PSD) compared to conventional granular media filtration processes. If CMF effluent PSD is relatively poor, it may impact disinfection performance, in particular UV disinfection. To address these issues and to evaluate the overall performance of this technology, pilot-scale testing was conducted in January of 2007. This paper summarizes the results of the pilot testing.

Objectives

The Districts' conducted a pilot-scale evaluation the AquaDisk® CMF manufactured by Aqua-Aerobic Systems, Inc., of Rockford, Illinois (Aqua-Aerobic). Testing was carried out at the Districts' San Jose Creek West WRP (SJCW WRP) because anthracite mono-media filters are employed at the plant and because polymer is added as a secondary clarifier settling aid. This allowed for a direct comparison of the two different filtration technologies considered. The objectives of the pilot study were: (1) evaluate the ability of the CMF to consistently meet Title 22 turbidity requirements while operating at both average and peak hydraulic loading rates; (2) determine the PSD of CMF effluent; (3) determine CMF backwash water volume requirements while operating at both average and peak hydraulic loading rates; (4) determine if polymer used as settling aid would impact CMF performance. For comparison, turbidity, particle size distribution, and filter hydraulic loading rate data were also collected for the SJCW WRP mono-media filters.

Pilot Equipment

The Aqua-Aerobic pilot plant contains one AquaDisk® filter element in an 800 gallon filtration tank (Figure 1). The disk is 3 ft in diameter and has an effective filtration area of approximately 12 ft². The disk is divided into two equal segments, each covered with a high-strength cloth media. For this study an acrylic pile fabric (MMK2-13) was tested. The media has a nominal pore size of 10 µm and the Title 22 approved peak hydraulic loading rate for the media is 6 gpm/ft².
The nominal filtration capacity of the pilot plant is 3.3 gpm/ft$^2$ (40 gpm) with a peak capacity of 6.5 gpm/ft$^2$ (78 gpm). The pilot plant is equipped with influent and effluent turbidity meters as well as influent and backwash flow meters. The plant is PLC-controlled and is equipped with a data logger for data storage and acquisition. All primary process parameters are logged at one-minute intervals. These parameters include influent and effluent turbidity, influent flowrate, and backwash flowrate. The pilot plant is also equipped with a two-stage chemical feed system, which is used to add coagulants to the filter influent to enhance turbidity removal. Components of the chemical feed system include feed pumps, a flash mixer, and two tanks in series equipped with variable speed mixers.

**Test Plan**

The CMF was tested at two different hydraulic loading rates; the Aqua-Aerobic recommended design average loading of approximately 3.3 gpm/ft$^2$ (40 gpm) and the maximum approved loading of 6 gpm/ft$^2$ (72 gpm). In addition, the filter was tested under two different influent turbidity conditions; normal and enhanced. The normal condition was to directly filter the SJCW WRP secondary effluent, which usually has low turbidity levels (<2 NTU). To evaluate the CMF under simulated poor clarifier performance, two runs were made with enhanced influent turbidity levels by adding mixed liquor to the secondary effluent. The targeted total suspended solids (TSS) range was 30 to 50 mg/L. These conditions were simulated over a 4-hour period.

Throughout the pilot testing study, influent and effluent turbidity were continuously monitored with the Aqua-Aerobic pilot plant meters. Periodic grab samples were also collected and analyzed for turbidity to verify the online results. For comparison, continuous turbidity and hydraulic loading rate data were also collected for the SJCW WRP mono-media filters. To evaluate CMF effluent PSD, an online particle counter (Hach 2200 PCX) was used to continuously monitor the filter effluent. Grab samples of CMF effluent and SJCW WRP filter effluent were also analyzed for comparison.
Table 1 - CMF and SJCW WRP Turbidity Data

<table>
<thead>
<tr>
<th>Filter</th>
<th>Hydraulic Loading Rate (gpm/ft²)</th>
<th>Influent Turbidity Condition</th>
<th>Average Influent (NTU)</th>
<th>Average Effluent (NTU)</th>
<th>% Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMF 3.3</td>
<td>Normal</td>
<td>1.4</td>
<td>0.82</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>CMF 6.0</td>
<td>Normal</td>
<td>1.4</td>
<td>0.80</td>
<td>43</td>
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</tr>
<tr>
<td>CMF 3.3</td>
<td>Enhanced</td>
<td>20.6</td>
<td>1.5</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>CMF 6.0</td>
<td>Enhanced</td>
<td>14.3</td>
<td>1.7</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>SJCW WRP</td>
<td>2.7</td>
<td>Normal</td>
<td>1.2</td>
<td>0.83</td>
<td>31</td>
</tr>
</tbody>
</table>

Results

Turbidity

One of the primary objectives of the pilot study was to evaluate the ability of the CMF to consistently meet Title 22 turbidity requirements. The criteria specified in Title 22 state that effluent turbidity should not exceed (1) an average of 2 NTU within a 24-hour period, (2) 5 NTU more than 5 percent of the time within a 24-hour period, and (3) 10 NTU at any time. CMF turbidity monitoring data are summarized in Table 1 and a typical trend is shown in Figure 2. For reference, average turbidity and hydraulic loading rate data for the SJCW WRP filters are also shown in Table 1.

Figure 2 - Typical CMF Turbidity Trend
Overall, the results show that the CMF was capable of meeting Title 22 effluent turbidity requirements under both average and peak hydraulic loading conditions. Under normal influent turbidity conditions, the average effluent turbidity was always less than 1 NTU. However, because the average influent turbidity was always less than 2 NTU, the CMF was not significantly challenged during these operating periods. The ability of the CMF to remove turbidity was best demonstrated under enhanced influent turbidity conditions. Influent and effluent turbidity trends for each of the enhanced turbidity tests are shown in Figures 3 and 4. At the design average hydraulic loading rate of 3.3 gpm/ft$^2$ (Figure 3), the average and peak influent turbidities were 20.6 and 27.7 NTU, respectively. The effluent turbidity ranged between 0.92 and 2.7 NTU with an average of 1.5 NTU. At the peak hydraulic loading rate of 6.0 gpm/ft$^2$ (Figure 4), the average and peak influent turbidities were 14.3 and 16.7 NTU, respectively. The effluent turbidity ranged between 0.98 and 2.4 NTU with an average of 1.7 NTU.

**Figure 3 - CMF Enhanced Turbidity Testing (Average HLR)**
Particle Size Distribution

To evaluate the CMF effluent particle size distribution (PSD), an online particle counter (Hach 2200 PCX) was used to continuously monitor the filter effluent. In addition, periodic grab samples of SJCW WRP secondary effluent, filter effluent, and CMF effluent were analyzed for comparison. The SJCW WRP secondary effluent samples were collected from the filter influent channel at the same location that fed the CMF.
A typical CMF PSD trend is shown in Figure 5. The trended particle size ranges include 0-2 µm, 2-5 µm, 5-10 µm, and 10-20 µm. Data for eight size ranges were actually recorded, however particle counts in the larger size ranges were negligible. Although this trend is for operation at the peak hydraulic loading rate of 6 gpm/ft$^2$, similar trends were observed while operating at 3.3 gpm/ft$^2$. The trended data illustrate the ability of the CMF to remove particles smaller than the nominal pore size of 10 µm. At the start of a filtration cycle (just after a backwash), the filter fabric is clean and allows higher numbers of small particles to pass. However, as the filtration cycle proceeds, these particles are removed due to the formation of a mat of rejected solids on the surface of the filter fabric. Another important observation is that particles in the 10-20 µm size range make up a negligible fraction of the total particle count. Particle counts were typically non-detect to 10 per mL throughout the pilot study. Particles in this size range and larger are of importance if UV disinfection is considered after the CMF process. These particles can potentially shield organisms from UV light and reduce the effectiveness of the disinfection process.
A grab sample comparison of PSD for the CMF and SJCW WRP filter effluent is shown in Figure 6. As shown in the figure, the CMF effluent had higher particle counts than the mono-media filter effluent at similar hydraulic loadings rates. However, the counts were not significantly higher and the detected particles were not in the size range (10-20 µm) that could potentially hinder UV disinfection performance.

**Backwash Water Volume Requirements**

To evaluate backwash water volume requirements for the CMF, data such as backwash duration, average backwash flowrate, and time between backwashes were recorded. From this information the backwash volume requirements as a percentage of filter throughput was calculated for each operating period. During operation of the CMF, the backwash duration was set at one-minute and the backwash pump flowrate was set at 80 gpm (6.7 gpm/ft²). The backwash cycle was initiated when the water level in the filtration tank reached 5.3 ft from an initial operating level of 4 ft. However, a default backwash was initiated after a filter run-time of four hours if the water level did not reach 5.3 ft in that period.

**Table 2 - CMF Backwash Water Volume Requirements**

<table>
<thead>
<tr>
<th>Hydraulic Loading Rate (gpm/ft²)</th>
<th>Influent Turbidity Condition</th>
<th>Average Influent Turbidity (NTU)</th>
<th>Backwash Frequency (times/day)</th>
<th>Backwash Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>Normal</td>
<td>1.4</td>
<td>6 - 7</td>
<td>0.83 - 0.97</td>
</tr>
<tr>
<td>6.0</td>
<td>Normal</td>
<td>1.4</td>
<td>13 - 17</td>
<td>1.0 - 1.4</td>
</tr>
<tr>
<td>3.3</td>
<td>Enhanced</td>
<td>20.6</td>
<td>90</td>
<td>12.5</td>
</tr>
<tr>
<td>6.0</td>
<td>Enhanced</td>
<td>14.3</td>
<td>234</td>
<td>18.0</td>
</tr>
</tbody>
</table>
Calculated backwash volume requirements for each test run are shown in Table 2. For filter runs at 3.3 gpm/ft² and normal influent turbidity conditions, the backwash volume ranged between 0.83% and 0.97% of the total filter throughput volume. At a loading of 6.0 gpm/ft² and normal influent turbidity conditions, the backwash volume ranged between 1.0% and 1.4%. As would be expected, the backwash volume increased significantly, to between 12.5% and 18%, during the enhanced influent turbidity testing periods.

Based on information provided by Aqua-Aerobic, backwash volume requirements for full-scale AquaDisk® systems are typically less than what is achieved during pilot-scale testing; less than 5% up to an influent TSS concentration of 20 mg/L. The difference in performance is due to the higher backwash rate, 6.7 gpm/ft², used for the pilot system. In full-scale systems, two disks are backwashed using one pump at 130 gpm. Each disk is 7 ft in diameter with an approximate filtration area of 54 ft². Thus, the backwash rate is 1.2 gpm/ft², which is significantly lower than that used for the pilot system.

Polymer

Another important objective of the pilot study was to determine if polymer used as a secondary clarifier settling aid had an impact on CMF performance. At the SJCW WRP, cationic polymer (Polydyne SW-037) is added to the mixed liquor channel before entering the secondary clarifiers at a dose of approximately 1 ppm. Throughout the pilot study, there was no apparent clogging or matting of the CMF due to polymer addition.

Summary

Results of the CMF pilot study are summarized below.

- The CMF was capable of meeting Title 22 effluent turbidity requirements under both average and peak hydraulic loading conditions and under high solids loading conditions.
- CMF effluent particle counts were not significantly different than the SJCW WRP mono-media filter effluent under similar filter loading conditions. Particles in the size range (10-20 µm) that could potentially hinder UV disinfection performance made up a negligible fraction of the total particle counts.
- For filter runs at 3.3 gpm/ft² and normal influent turbidity conditions, the backwash volume ranged between 0.83% and 0.97% of the total filter throughput volume. At a loading of 6.0 gpm/ft² and normal influent turbidity conditions, the backwash volume ranged between 1.0% and 1.4%. The backwash volume increased significantly, to between 12.5% and 18%, during the enhanced turbidity testing periods.
- Throughout the pilot study, there was no apparent impact of polymer used as a secondary clarifier settling aid on CMF performance.