

# **EVALUATION AND DESIGN OF A CLOTH DISK FILTER TO MEET TITLE 22 REUSE CRITERIA**

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## **ABSTRACT**

The City of Manteca (City) Regional Wastewater Quality Control Facility (WQCF) is adding filtration and UV disinfection facilities to meet California Title 22 wastewater reuse criteria. The cloth disk filter (CDF), manufactured by Aqua-Aerobic Systems, Inc. (AAS) was evaluated and selected as the technology for use at the WQCF. The evaluation process included a pilot filter study, researching historical operating performance of the filter, site visits to existing reclamation plants, and contact with facilities in the process of constructing or starting-up the CDF.

Results from the pilot filter study indicated that the CDF was a feasible filtration technology for the WQCF which would meet Title 22 effluent requirements and provide adequate particle removal for effective downstream UV disinfection. References from existing CDF plants confirmed the operational reliability and low-maintenance requirements for the CDF. Final selection of the CDF was implemented after City personnel and design engineers visited several operational CDF facilities. A second site visit at additional CDF facilities aided in determining design features for the 20 mgd filtration process at the WQCF and in identifying potential start-up issues.

## **INTRODUCTION**

The City of Manteca (City) Regional Wastewater Quality Control Facility (WQCF) is adding filtration and UV disinfection facilities to meet California Title 22 (Title 22) wastewater reuse criteria. The WQCF is a combined biofilter-activated sludge plant that has been upgraded recently to full nitrification, with future addition of denitrification scheduled in the year 2005/2006. A variety of technologies exist for the filtration of secondary effluent to meet Title 22 requirements. The cloth disk filter (CDF), manufactured by Aqua-Aerobic Systems, Inc. (AAS) was evaluated and selected as the technology for use in the expansion and upgrade of the WQCF.

## **PURPOSE AND OBJECTIVES**

The principal objective of the filtration design was to provide the City with a reliable, cost effective, and easily maintained filtration system for secondary effluent, with specific reference to Title 22 wastewater reuse criteria. This objective was attained through a multi-step process for evaluating the selected filtration technology which included: 1) a pilot filter study at the WQCF, 2) researching historical operating performance, 3) site visits to existing facilities, and 4) contacts with plants under construction or in the process of starting-up with filters. The information collected during these steps was then incorporated into the design of the CDF for the City.

## **DESCRIPTION OF CLOTH DISK FILTER (CDF)**

The CDF involves the use of a cloth membrane as the filter medium. The cloth membrane is a simple random weave fabric that is used to separate the particles from the fluid to be filtered.

The density and thickness of the filter cloth is selected according to the characteristics of the influent wastewater and desired effluent quality. Disks covered by the cloth membrane are mounted vertically to a common hollow tube. The number of disks mounted on the tube can be varied depending on the filtration area required. Wastewater passes through the cloth membrane by gravity, and enters inside the filter disks. Filtered effluent is conveyed through the hollow tube. The filter is quiescent during the filtration operation, which allows larger particles to settle to the bottom of the tank. The sedimentation of larger size particles within the filter basin decreases the amount of solids to be filtered. An individual full scale filter disk is divided into six equal segments with a total surface area of approximately 54 ft<sup>2</sup>.

The pressure loss across the membrane increases as more particles are accumulated and a mat is formed on the surface of the membrane. The backwash operation is started when the terminal headloss (usually 12 inches of water) or a certain run time is reached. Accumulated particles are removed from the surface of the cloth membrane by liquid suction applied to each side of the disk. Disks rotate slowly (approximately one revolution per minute) allowing each segment to be cleaned. A backwash vacuum shoe is mounted on each side of the filter disk. The accumulated solids are vacuumed from the media as the disk rotates past the shoes. Filtration occurs through the remainder of the filter disk resulting in continuous filtration operation. The vacuuming effect is created through the use of a backwash pump. Filtered water is used for backwash, therefore a separate clean water tank is not required as part of the backwash system. Disks are usually backwashed in multiples of two. Large particles which have settled in the filter basin are removed through sludge assembly piping connected to the backwash pumps. The backwash system typically consists of one to two backwash pumps (depending on the number of disks within the filter basin), sludge assembly piping, motorized valves, and associated piping. The backwash system is often located to the side of a filter basin in a pump gallery at the same elevation as the filter disks.

The CDF is offered as a package system, which includes metal tanks for the filter, or can be installed within a concrete basin. The CDF has been in operation since 1994. The filter is typically chosen for its small footprint, minimal maintenance and backwash requirements, and low initial capital cost.

## **PILOT FILTER STUDY AT MANTECA WQCF**

A pilot filter study with a CDF was conducted from December 9, 2003 through January 16, 2004 at the Manteca WQCF. Two filtration rates and chemical addition using several different chemicals and doses were evaluated for varying influent total suspended solids concentrations. Filter runs ranged from approximately three hours to one week (with multiple backwash cycles within a single filter run) depending on the conditions tested.

### **Objectives of Pilot Filter Studies**

The principal objective of the filtration studies was to evaluate the performance of the CDF with WQCF secondary effluent with specific reference to Title 22 wastewater reuse criteria. Supporting objectives included: (1) the quantification of CDF operating characteristics, (2) evaluation of the filter reliability and performance as affected by variations in filter influent quality and filtration rate, (3) determination of the backwash water requirements, and (4) assessment of the effect of the filter performance on disinfection efficiency. Effluent quality was the major criterion to assess the filter performance.

### **Description of Pilot Filter**

AAS provided a trailer mounted AquaDisk™ pilot test system. The pilot facilities consisted of a submersible pump to provide the required flow to the system, chemical addition system, a one-disk cloth media filter with 12 square feet of effective filter area (with two segments), magnetic flow meters, effluent, overflow, backwash, and drain lines from the unit. The pilot unit employed a PA-13 pile cloth as the filtering medium which has a nominal pore size of 10 microns.

A two stage chemical feed and flocculation system was used in experiments with chemical addition. The chemical addition system included a coagulant feed pump, a flash mixer, a polymer feed pump, and two mixing tanks in series (each equipped with a variable speed mixer).

The system was furnished with continuous turbidity and particle size sampling equipment and a data logging system. Influent and effluent sampling ports were used for grab samples to be analyzed in the WQCF laboratory. Pilot filter characteristics are listed in Table 1.

**Table 1 – Aqua Disk Pilot Filter Characteristics**

Filter Surface Area, ft <sup>2</sup> (Submerged)	Filter Dimensions (WxLxH), ft	Normal Hydraulic Loading Rate		Maximum Hydraulic Loading Rate		Filter Medium	
		Flow, gpm	Filtration rate, gpm/ft <sup>2</sup>	Flow, gpm	Filtration rate, gpm/ft <sup>2</sup>	Type	Nominal pore size, μm
12	9x45x13.5	39	3.25	78	6.5	PA-13 pile cloth <sup>a</sup>	10

<sup>a</sup> Filter medium involving the use of nylon fiber material

The influent for the pilot test system was delivered by a submersible, 3-HP pump to supply flow up to 78 gpm. The submersible pump was placed in the secondary effluent collection box. Backwash reject water was returned to the head of the plant.

### Filter Performance Data

Field parameters that were monitored to assess the performance of the filter included: (1) turbidity, (2) total suspended solids (TSS), (3) particle size distribution (PSD), and (4) transmittance. Parameters were monitored for both filter influent and effluent. The backwash and influent flow rate were also measured to monitor operational parameters such as backwash ratio and effective filtration rate. The influent flow was monitored using a Krohne IFC020D magnetic flow meter. The backwash flow was monitored using an ABB Model 10D1475 magnetic flow meter.

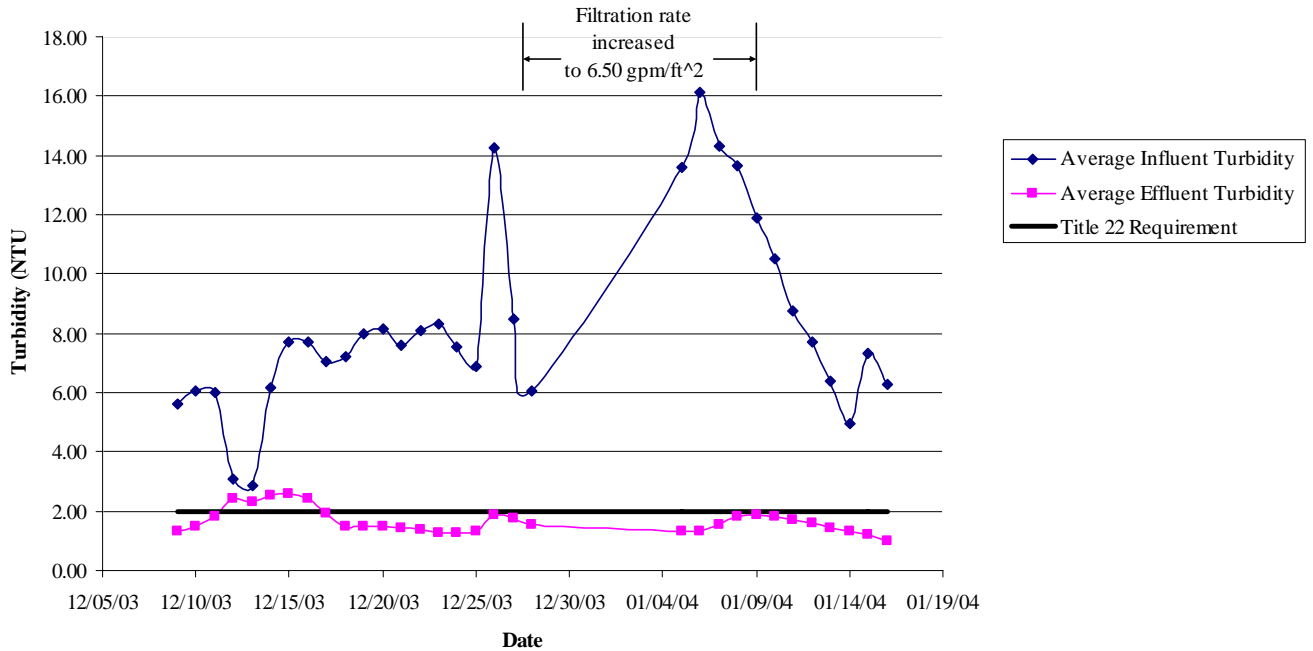
### Turbidity

Influent turbidity and effluent turbidity were monitored continuously with two Hach Model 1720 D low range process turbidimeters. The monitored results were recorded every 30 seconds using the data logging system. Filter effluent turbidity values were compared with the Title 22 turbidity requirements to determine if Title 22 approval would be achieved using the CDF with WQCF secondary effluent.

Daily average influent and effluent turbidity values observed during the entire period of the testing program are shown in Figure 1. The filter was left unattended between December 29, 2003 and January 4, 2004 due to the holidays. Results obtained during this period were not

included in the evaluation because of the questionable influent turbidity data.

**Figure 1 – Manteca WQCF Pilot Filter Study – Average Daily Influent and Effluent Turbidity**



**Filter runs without chemical addition:** The daily average effluent turbidity was observed to be below 2 NTU (Title 22 requirement), between 1.29 NTU and 1.90 NTU, for 23 days. Daily average influent turbidity values were between 5.64 NTU and 14.27 NTU for these 23 days. Daily average effluent turbidity exceeded 2 NTU for 7 days (between 2.17 and 2.61) for the daily average influent turbidity values between 2.86 NTU and 15.13 NTU.

**Filter runs with chemical addition:** Coagulant and polymer addition was evaluated at concentrations ranging from 2.5 – 15 mg/L and 0.05-0.20 mg/L, respectively. Turbidity results were evaluated for filter runs conducted with chemical addition for 10 days. The daily average effluent turbidity was observed to be below 2 NTU for nine of these runs (between 0.99 NTU and 1.93 NTU) for daily average influent turbidity values between 6.45 NTU and 18.44 NTU. The daily average effluent turbidity was 2.05 NTU on January 8, 2004 for a daily average influent turbidity value of 14.15 NTU. Polymer was not added on that day and the only coagulant was applied at a low concentration of 2.5 mg/L.

**Filter runs to simulate upset conditions:** Filter runs were conducted on January 14, 2004 and January 15, 2004 to evaluate the performance of the CDF without chemical addition subject to upstream process upsets. Plumbing modifications were made to mix return activated sludge with the secondary effluent before the pilot filter. The daily average influent turbidity was 34.08 NTU on January 14, 2004. Average daily and maximum effluent turbidity values were observed to be 6.06 NTU and 8.49 NTU, respectively. The daily average influent turbidity was 44.84 NTU on January 15, 2004. Average daily and maximum effluent turbidity values were observed to be 4.51 NTU and 8.64 NTU, respectively.

**Filter runs at higher filtration rate:** Filter performance was also evaluated at a higher filtration rate (twice the design filtration rate for average plant flows) from December 26, 2003 through January 6, 2004, and from January 12-13, 2004. All of the runs at higher filtration rate were performed without chemical addition. The daily average effluent turbidity was observed to be below the Title 22 turbidity requirement (2 NTU) for these runs (between 1.34 - 1.87 NTU) for daily average influent turbidity values between 5.94 NTU and 14.27 NTU.

#### Total Suspended Solids (TSS)

Influent and effluent TSS values were measured for grab samples collected three times a day from December 12, 2003 through December 21, 2003 and from January 5-16, 2004. TSS measurements were performed at the WQCF laboratory in accordance with the guidelines in *Standard Methods for the Examination of Water and Wastewater*, 20<sup>th</sup> Edition.

The average effluent TSS for all the grab samples collected during the pilot study was 2.8 mg/L (for an average influent TSS value of 13.7 mg/L). The average daily effluent TSS concentrations ranged from 0.47 mg/L to 7.23 mg/L for average daily influent TSS concentrations from 6.93 mg/L to 25.60 mg/L.

**Filter runs to simulate upset conditions:** The influent TSS concentration was observed at 147 mg/L for a sample collected on January 14, 2004 during the filter run to simulate upstream plant upset conditions. The effluent TSS was 11 mg/L for this period.

**Filter runs at higher filtration rate:** The performance of the filter was evaluated at a higher filtration rate (6.50 gpm/ft<sup>2</sup>). Average influent and effluent TSS values (for samples collected during higher filtration rate runs) were 18 and 1.8 mg/L, respectively for January 5-6, 2004. The effluent TSS value was 2.4 mg/L for an influent TSS value of 15 mg/L on January 6, 2004.

#### Particle Size Distribution (PSD)

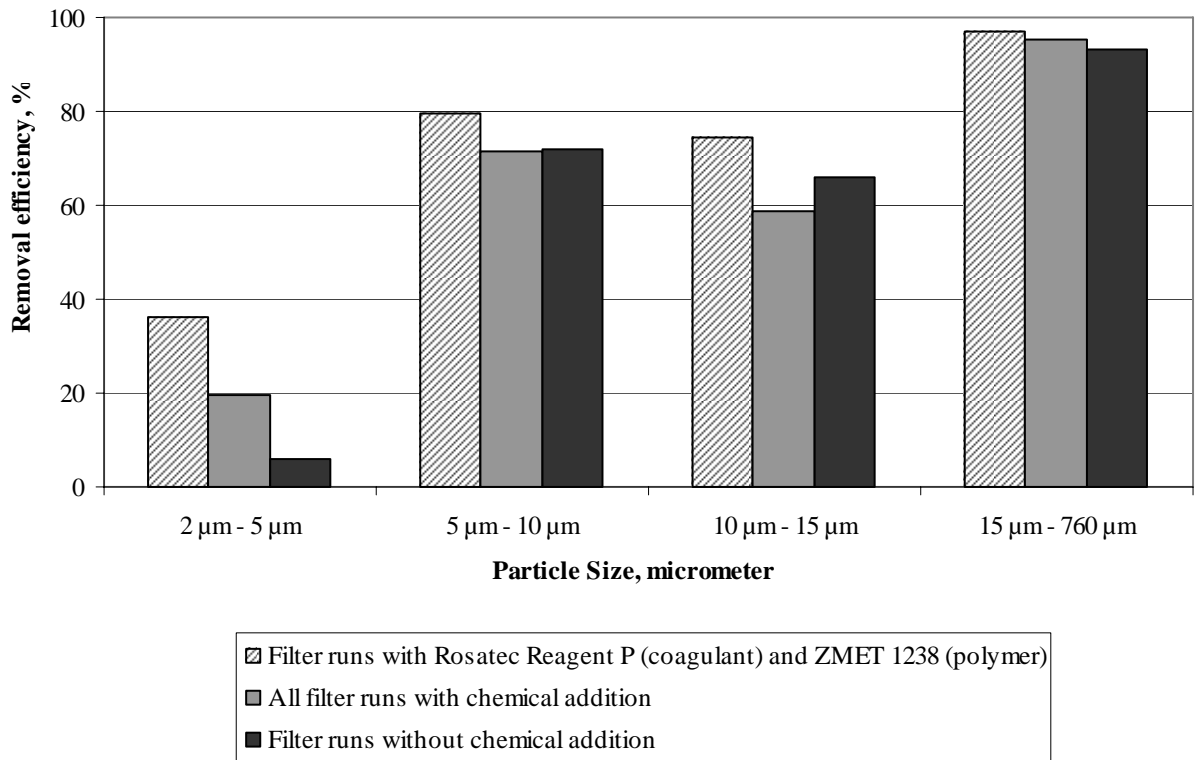
UV disinfection efficiency is greatly affected by the performance of the upstream filtration process in terms of turbidity, TSS removal, and PSD of the filtered effluent. Large particles provide better shading and shielding effects than smaller particles. Particles larger than 20 µm in size can easily be removed by almost all wastewater filtration technologies. The efficiency of filtration technologies vary significantly for the removal of particles smaller than 20 µm in size. Particles between 5 to 10 µm and 20 µm still provide significant shading and shielding effects for pathogens during the disinfection process. Therefore, poor disinfection efficiencies can still be expected if the filter effluent contains a considerable amount of suspended particles between 5 to 10 µm and 20 µm even if the filtered effluent turbidity is less than 2 NTU. Particles smaller than 5 µm to 10µm in size are not as problematic for disinfection purposes.

Influent PSD and effluent PSD were monitored continuously with two Hach 2200 PCX particle counter units and recorded every 30 seconds using the data logging system. Installation and adjustment of the particle size equipment to obtain the desired data were completed on December 18, 2004. Clogging of the influent particle size sampling lines due to large size particles required frequent cleaning of the influent sampling lines and equipment. A screen was installed in the particle size influent sampling line on December 19 to help prolong particle meter run times.

The performance of the CDF was evaluated for the following four particle size ranges: (1) between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ , (2) between 5  $\mu\text{m}$  and 10  $\mu\text{m}$ , (3) between 10  $\mu\text{m}$  and 15  $\mu\text{m}$ , and (4) between 15  $\mu\text{m}$  and 760  $\mu\text{m}$ . Removal efficiencies for the particles between 5  $\mu\text{m}$  and 10  $\mu\text{m}$  and between 10  $\mu\text{m}$  and 15  $\mu\text{m}$  were used as the major criteria to evaluate the effect on downstream UV efficiency for the reasons mentioned above.

As expected, removal efficiency was quite high for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  in size and was very low for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ . The average removal efficiencies were 93 percent and six percent for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  and for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ , respectively for filter runs conducted without chemical addition (see Figure 2). The average removal efficiencies were 72 percent and 66 percent for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$  and for particles between 5  $\mu\text{m}$  and 15  $\mu\text{m}$ , respectively as shown in Figure 2.

**Figure 2 – Manteca WQCF Pilot Filter Study Average Removal Efficiency for Various Particle Sizes**



The effect of chemical addition on removal efficiency was observed to be greater for smaller particles. Chemical addition increased the average removal efficiency from 6 percent to 20 percent for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ . The increase in the removal efficiency for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  was less than five percent as seen in Figure 2. Another key conclusion from Figure 2 is the importance of chemical selection to increase the filtration efficiency. Higher removal rates were achieved with the use of a polymer type, ZMET 1238, when compared to results for the other three polymers tested. The removal efficiencies for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$  and for particles between 5  $\mu\text{m}$  and 10  $\mu\text{m}$  had increased to 36 percent and 80 percent with polymer type ZMET 1238.

## Transmittance

Another important criterion for UV effectiveness is transmittance. UV efficiency increases as the transmittance (254 nm transmittance) increases and filtration generally increases transmittance. The performance of the CDF in terms of transmittance was evaluated to determine if the UV transmittance design criteria objective of 55 percent would be achieved.

Influent and effluent transmittance values were measured for grab samples collected three times a day from December 12, 2003 through December 16, 2003 and from January 5, 2004 through January 16, 2004. Secondary effluent transmittance values ranged from 37.5 percent to 67.7 percent with an average value of 58.9 percent. Filtered effluent transmittance values ranged from 54.8 percent to 70.5 percent with an average value of 62.6 percent.

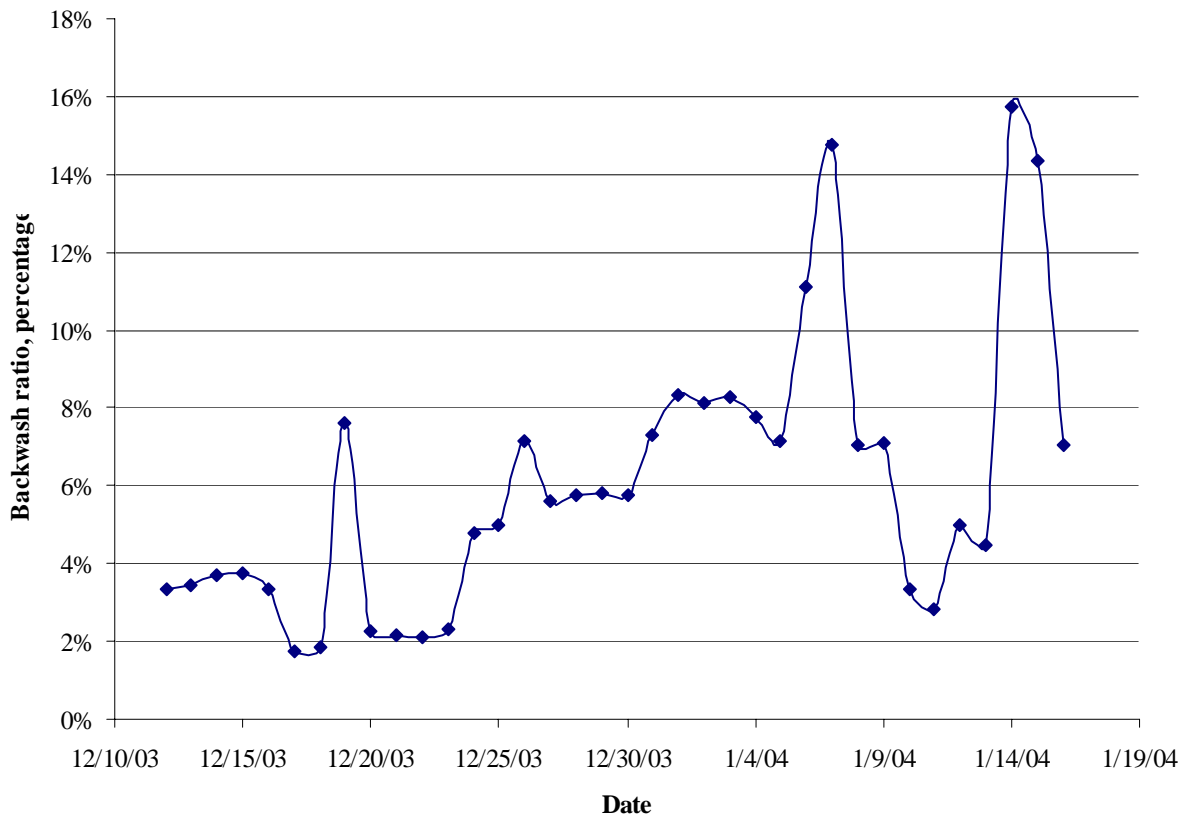
## Backwash Ratio

The following operational parameters were monitored to calculate the net water production rate and the backwash ratio:

1. Filtration rate (in gpm)
2. Backwash flow rate (in gpm)
3. Length of filtration period (in minutes)
4. Length of backwash cycle (in minutes)

The daily average backwash ratio ranged from 1.7 percent to 16 percent with an average value of 6 percent as seen in Figure 3. As expected high backwash ratios (from approximately 14 percent to 16 percent) were observed on January 13, 2004 and January 14, 2004 as a result of high solids loading conditions tested on these days. High backwash ratios from approximately 11 percent to 15 percent were also observed on January 6, 2004 and January 7, 2004. Influent turbidity values were unusually high (from approximately 14 NTU to 16 NTU) during these days due to cleaning of the secondary clarifier weirs.

**Figure 3 – Manteca WQCF Filter Pilot Study Average Daily Backwash Ratio**



### **Pilot Study Conclusions**

Conclusions drawn from the pilot study conducted at the WQCF are summarized below:

1. At a filtration rate of 3.25 gpm/ft<sup>2</sup> Title 22 turbidity requirements are expected to be achieved with the CDF for daily average influent turbidities up to 9 - 10 NTU without chemical addition. With chemical addition the Title 22 turbidity requirements were satisfied up to a daily average influent turbidity of 18 NTU.
2. Based on filter runs conducted at 6.5 gpm/ft<sup>2</sup>, TSS and turbidity removal performance of the filter did not appear to decrease with the increase in the filtration rate.
3. Based on tests conducted to simulate plant upset conditions, filter effluent turbidity was between 5 NTU and 10 NTU for influent turbidities between 20 NTU and 80 NTU.
4. The average effluent TSS was less than 10 mg/L during normal plant operating conditions (filter influent TSS less than 30 mg/L).

5. The CDF produced an effluent with TSS between 20 mg/L to 30 mg/L for plant upset conditions (with filter influent TSS values between 100 - 150 mg/L).
6. Based on PSD results, filtration of secondary effluent using CDF would enhance the efficiency of the downstream UV disinfection process by removing the residual particles (from 66 percent to 93 percent depending on the particle size range) that are disinfection barriers.
7. The UV transmittance design criteria objective of 55 percent was achieved with the CDF.
8. The average backwash water ratio was observed to be approximately 6 percent during the pilot study.

## **HISTORICAL OPERATING EXPERIENCE**

The pilot filter study demonstrated the feasibility of the CDF for use at the WQCF. Additionally, eight wastewater treatment plants with the CDF were surveyed to evaluate the operational history of the CDF. The treatment plants contacted were selected based on the number of years the CDF has been in operation, size of the treatment facility, facility location, and production of recycled water. Most of the existing CDF installations are at small treatment plants with influent flows less than 2 mgd. There are over 250 installations worldwide with approximately thirty in the United States. At the time of the survey, less than five operational CDF installations existed in California.

Fifty percent of the CDF facilities contacted had an upstream sequencing batch reactor. The other fifty percent of the treatment facilities had activated sludge and secondary clarifiers prior to the filters. Operators reported that the filter required minimal operator attention, had no major maintenance problems, and operated with a typical backwash ratio of less than 5 percent. Most of the facilities did not use chemical addition prior to the filters. The greatest limitation associated with the CDF was the low removal rates for particles smaller than the cloth size. Overall, the references recommended this type of filter for treatment plants. All of the references indicated that the CDF was able to handle high turbidity influent and process upsets well, but with a resulting increase in backwash rate. Two references mentioned that the cloth filter does not remove color well, which can be encountered when algae is present or with certain industrial processes. Three of the treatment plants contacted used UV disinfection downstream of the CDF. None of the three treatment plants had problems meeting their waste discharge requirements for coliform.

## **SITE VISITS**

Two site visits to operational CDF facilities were conducted. During the first site visit, design engineers and City personnel visited CDF facilities as well as membrane disk filter facilities (a similar type of filtration technology). Based on the layout of the filtration facilities, operational data, and interviews with operators, the CDF was selected as the future filtration technology at the WQCF.

A second site visit with design engineers and representatives from AAS was conducted prior to beginning design. This site visit was useful for visualizing various CDF design layouts, conferring with operators as to useful design features, and requesting information from AAS. Two facilities in Arizona were visited. Both facilities had retrofitted existing filter basins with the CDF. Several observations resulted from the site visit including the need to:

1. Locate all of the backwash pumps in a separate building area.
2. Provide a catwalk within the filter basin.
3. Customize PLC panels and programming to match existing technology used at the facility.
4. Install a removable sunshade cover to allow crane access to the filters if needed.
5. Provide adequate space and accessibility to the filter basins and pump galleries.

### **ADDITIONAL FEEDBACK FROM FACILITIES WITH RECENT CDF INSTALLATIONS**

The California Department of Health Services (DHS) approved the CDF for use in the production of recycled water in 2002. Since DHS acceptance of the CDF for Title 22, several large facilities in California have selected the CDF for installation. Three facilities in particular, two of which were in the vicinity of the City, were contacted. The following useful information was gathered with regard to the design of the CDF facilities:

1. Provide additional space within the filter basins and pump galleries than typically suggested.
2. Turbidimeters on the effluent of each individual filter would be useful.
3. Provide easy access to the pump galleries.
4. Provide a canopy or roof over the filters to make it easier to see the control panel screens and limit algae growth within the filter basins.
5. Use steel or ductile iron piping for the backwash system.

The following start-up operational information was also gathered from these facilities:

1. Expect a two to four week “seasoning” period for the filters during initial start-up. The effluent turbidity will improve and eventually stabilize over this time period. Ideally the filters should run continuously during this period.
2. Do not have more than one backwash cycle operate at a time if there are multiple filtration units. After a backwash, the effluent turbidity will increase slightly.
3. Do not change the fabric for more than one filter unit at a time to avoid an unexpected increase in effluent turbidity due to the “seasoning” period.

### **CONCLUSIONS**

The CDF is a recent filtration technology which has typically been selected for its small footprint, minimal maintenance and backwash requirements, and low initial capital cost. A pilot filter study with the CDF indicated that the CDF was a feasible filtration technology for the Manteca WQCF which would meet Title 22 effluent requirements and provide adequate particle removal for effective UV disinfection. References from existing facilities with the CDF

confirmed the operational reliability and low-maintenance requirements claimed by the manufacturer. Final selection of the CDF was decided after site visits to operational CDF facilities by City personnel and design engineers. A second site visit and follow-up with more recent CDF facilities aided in determining design features for the filtration facilities at the WQCF and identifying potential start-up issues.

## **ACKNOWLEDGMENTS**

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## **REFERENCES**

Nolte Associates, Inc. (2004) *City of Manteca Wastewater Quality Control Facility Phase III Expansion Project Schedule D – Effluent Filtration and UV Disinfection Assessment of Aqua Aerobic Systems Cloth Disk Filter for the Filtration of Secondary Effluent*; Manteca, CA.