THE USE OF CLOTH MEDIA FILTRATION ENHANCES UV DISINFECTION THROUGH PARTICLE SIZE REDUCTION

Michael Olivier, Aqua-Aerobic Systems, Rockford, IL
John Perry, City of San Bernardino Municipal Water Dept., San Bernardino, CA
Chris Phelps, City of San Bernardino Municipal Water Dept., San Bernardino, CA
Adam Zacheis, Carollo Engineers, Santa Ana, CA

Introduction

The San Bernardino Municipal Water Department (SBMWD) in California operates two treatment plants which combine to provide 32 MGD of secondary effluent to a Rapid Infiltration and Extraction (RIX) facility. At this facility, 25 MGD of the secondary effluent is sent to percolation ponds. Approximately 42 MGD is withdrawn from the soil and combined with the remaining 7 MGD of secondary effluent after it has been treated for water reuse. The water is sent to the Santa Ana River and subsequently treated for drinking water downstream. The water quality from the RIX facility must meet California's Title 22 requirements. The plant currently operates continuous backwash upflow deep bed sand filters followed by UV disinfection and have occasionally experienced disinfection violations on Total Coliforms.

The Water Department staff has suspected particle size as a potential culprit because coliform is thought to be shielded from UV light within particles of 10 microns in diameter or larger. Experiments were conducted using the AquaDisk® cloth media filter to determine its effectiveness at removing larger particles and subsequently enhancing UV disinfection. The cloth media filter was tested both as a polishing step to and in parallel with the existing sand filters. Data collected on turbidity, particle size, and UV dosage demonstrate that the AquaDisk® cloth media filter is an effective solution to enhance UV disinfection at the RIX facility.

Background

Recycled water regulations are contained in the California Code of Regulations, Title 22, Division 4, Chapter 3, Section 60301 through 60355. Title 22 specifies treatment requirements depending on the application in which the water will be used. Because of the potential for human contact in water reuse applications, disinfection of pathogenic microorganisms is necessary to preserve public health. Pathogenic microorganisms can cause disease. They are historically measured in wastewater treatment facilities by counting Total Coliform, an indicator of pathogens. Tertiary filtration reduces the number and size of particles that get sent to the disinfection process, which improves its effectiveness. Therefore, filtration and disinfection work together to reliably reduce pathogens and ensure public health. Specific guidelines have been developed for key parameters and are outlined in Table 1.

Table 1. Title 22 Effluent Limits

Parameter	Units	Guideline
Turbidity	NTU	< 2.0 (24 hour average) < 5.0 (95% of time) <10.0 (100% of time)
Total Coliform	MPN/100 mL	< 2.2 (7 day median) <23 (29 out of each 30 days) <240 (100%)

At wastewater treatment facilities, the filtration process is responsible to meet the turbidity requirements, while the disinfection process is relied upon to meet the total coliform limits.

After commission of continuous backwash upflow deep bed sand filters at the RIX facility, SBMWD has found that the UV disinfection system occasionally does not achieve the required disinfection level of 2.2 MPN total coliform per 100 ml. These excursions occurred even though the sand filters were meeting the required < 2 NTU turbidity limits.

It has been hypothesized that a minimum particle size (wastewater specific, but on order of 10 µm) governs the ability to shield coliform bacteria from UV light. The plant personnel noticed large particles passing through the sand filters and determined that this potentially may be the cause of their total coliform excursions.

Cloth Media Filter

The cloth media filter employs a pile cloth media arranged in a disk configuration and is marketed under the trademark AquaDisk® by Aqua-Aerobic Systems, Inc. The pile cloth media is constructed of nylon pile fibers attached to a polyester support backing. A microscopic view of the media is shown in Figure 1. The California Department of Health Services (DHS) has recently approved this media and filter technology as acceptable for Title 22 reuse applications. A picture of the AquaDisk® filter is shown in Figure 2.

Each disk is comprised of six equal segments. The cloth media is sewn in a sock configuration and slipped over each rigid hollow segment. The disks are mounted vertically to a central filtrate collection header. The vertical orientation of the disks allows the filter area to exceed the footprint area. The effluent flows by gravity through the filter. As solids buildup on the cloth, the head loss increases, causing a rise of the water level in the filter tank. Once a predetermined level is reached, an automatic backwash sequence is activated.

Another feature of this filter is the use of an intense, but small area backwash. By rotating the disk, the entire face of the disk is “vacuumed” to remove the solids that have accumulated on the surface of the cloth to restore the head loss. Solids continue to filter out during backwash.

Heavier solids can fall to the floor in between the disks and are evacuated periodically from the bottom of the filter tank via a solids collection manifold and the backwash pump. Solids removal frequency and duration is determined by programmed, adjustable setpoints in the PLC.

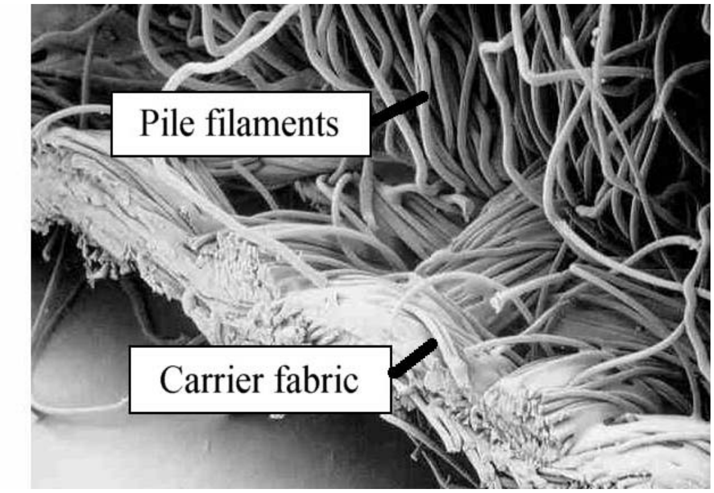

Figure 1. Microscopic View of Pile Cloth

The Joint Powers Authority (JPA) decided to pilot test the cloth media filter to determine its potential benefits with regard to the disinfection process, both operated in parallel or in series with the existing sand filters.

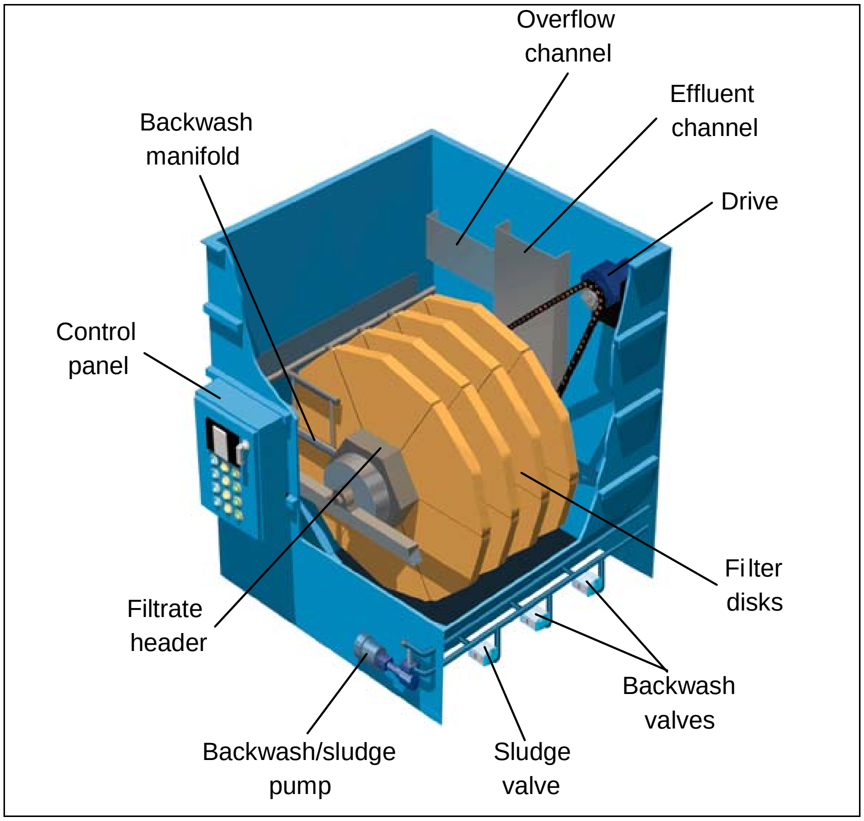

Figure 2. Schematic of the AquaDisk

Testing

A cloth media filter pilot unit was brought to the RIX facility and tested both parallel to and in series with the existing sand filters between March 15 and May 1, 2002. The purpose of the testing was to determine if the cloth media filter could enhance the UV systems ability to meet total coliform limits.

Samples were collected from the effluent of both the sand filter and the cloth media filter and analyzed for turbidity. Further, particle size analyses were performed on both filters and the secondary clarifier effluent. These samples were subsequently tested for UV disinfection.

Particle Size/Counting

For particle size analysis, an AccuSizer™ 780/SIS particle size analyzer was used. This particle size analyzer had the ability to count and size particles with diameters from 1 to 400 μm. Samples to be measured by the analyzer were drawn by a syringe pump through a small "photozone" (i.e., a narrow slab-like region of illumination that is produced by a light from a laser diode). As the sample passed through the photo or sensing zone, particles caused a detected pulse. The magnitude of this pulse depends on the diameter of the particle and the physical principal of detection (i.e., light scattering or light extinction). A particle size distribution was created one particle at a time by comparing the detected pulse heights to a calibration curve that was obtained from using a set of uniform latex sphere particles of known diameters.

The particle size analyzer system had a concentration limit of the number of particles that could be counted per volume (9,000 per ml). The presence of more than one particle in the sensing zone would result in the creation of a larger pulse magnitude, thus resulting in an erroneous particle size measurement. To prevent these erroneous results, the samples that were measured during this study were diluted with distilled particle free water. For these studies, the typical dilution of water samples was about 30 ml of sample per 100 ml of distilled water. Samples were analyzed immediately after collection.

The distilled water used for the dilution of the samples contained a very low number of particles (less than 200 particles/ml) and were smaller than approximately 5 μm. Therefore, the distilled water used for dilution would not give erroneous results through the contribution of large particles and was acceptable for use as a dilution media.

Collimated Beam UV Testing

The collimated beam used for all experiments was a Trojan low pressure, mercury lamp. This lamp emits 90 percent of its energy at a wavelength of 254 nm. The beam of UV light was passed through a 9-inch long, 3-inch diameter collimated beam to the water samples, which were continuously stirred on a stir plate.

The intensity at the end of the collimated beam was measured using a calibrated, International Light, SED240 UV sensor. The sensor is essentially a photovoltaic device that produces an electrical current when induced by a stream of UV light. This energy was measured with an International Light radiometer to convert light intensity into units of power-time per area. At the end of the collimated tube, the measured power output of the UV beam averaged around 0.2 mW/cm^2.

The irradiation of wastewater samples followed a relatively straightforward protocol to ensure accurate results. As mentioned previously, applied doses were based on the UV transmittance of the water samples and measured UV intensity. Two small doses, around 15 and 30 mJ/cm^2, were chosen to show the initial, rapid reduction of bacteria in samples. At least 5 different doses were chosen. An ultimate dose was one that would produce a total coliform count of less than 2.2 MPN/100 ml. The following methodology was used when performing all UV collimated beam experiments:

a) Allow the UV lamp to warm up for at least one hour before any testing to yield stable output intensity (approximately 0.2 mW/cm^2).
b) Measure the UV transmittance (254 nm) of the water sample and record.
c) Measure the initial UV intensity and record.
d) Place 100-ml (or less if dilution possible) of the water sample under the collimated beam and expose for the desired time period while constantly stirring on a stir plate.
e) Remove sample and re-measure the UV intensity.
f) Place irradiated sample in a dark and cool location until laboratory analysis.
g) Calculate the actual applied dose using Equation 1 based on the average applied UV intensity.

Results

Table 2 reports some of the key parameters of these tests, including the set-up (parallel [P] or series [S]) of the sand and cloth media filters, the turbidity readings for all the water samples, Total Suspended Solids (TSS) of the secondary effluent, and the UV transmissivities (UVT) for all water samples. Since TSS values were taken at one point during the day, they may not truly represent actual TSS levels in the secondary effluent at the time of testing. These values are presented to give a general indication of TSS levels on each testing day.

Table 2 . Test Results

		Sand Filter			Cloth Media Filter			Secondary Effluent
Date	Setup	Inf. Turb. (NTU)	Eff. Turb. (NTU)	UVT (%)	Inf. Turb. (NTU)	Eff. Turb. (NTU)	UVT (%)	TSS (mg/l)
3/15/02	P	4.0	1.8	70	4.0	1.3	70	10.2
3/20/02	P	3.9	1.6	69	3.9	1.5	70	5.9
3/27/02	S	4.0	2.3	65	2.3	2.1	70	18.9
4/3/02	S	2.6	1.1	70	1.2	1.0	70	8.1
4/11/02	P	5.4	2.7	71	5.4	1.7	72	22.8
4/18/02	P	3.6	2.6	71	3.6	1.9	70	8.9
4/25/02	P	3.2	1.2	69	3.2	1.9	69	7.2
5/1/02	P	2.0	1.4	71	2.0	1.5	71	6.0

Effluent turbidity and UVT was fairly comparable from both filters during the parallel operation. From 3/15 through 4/18, the cloth media filter produced slightly lower turbidity values. On 4/25 and 5/1, this trend reversed. It should be noted that, on 4/25, the sand filter was aided by the use of alum at 20 ppm, while the cloth media filter was run without supplemental chemicals. There was a marginal improvement in turbidity and UVT when the cloth media was operating in series, or downstream of the sand filter.

Particle Size Results

Samples collected from several days of testing were taken and analyzed for particle size distribution. During each of these days, particle size distributions were performed on the secondary effluent and the sand and cloth media filter effluents. These samples provided a "snapshot" of the particles for that part of the day.

As will be demonstrated in the following sections, particle size distribution graphs showed that the cloth media filter removed more particles than the sand filter. Table 3 lists the counts for some of the larger particles of interest (15 and 30 μm) for all three water types over each testing date. All but two of these dates, March 27, 2002 and April 3, 2002, were run in parallel. Parallel runs are shown in the top rows of Table 3, with the two runs in series at the bottom of the table.

Table 3. Selected Particle Counts

	Size [μm]	Date	Secondary Effluent [#/mL]	Sand Effluent [#/mL]	Cloth Media Effluent [#/mL]
Parallel	15	3/15/02	65	39	30
	15	3/20/02	220	73	11
	15	4/11/02	234	119	63
	15	4/18/02	181	165	142
	15	4/25/02	202	87	85
	15	4/25/02	202	87	58
	30	3/15/02	11	6	1
	30	3/20/02	23	9	2
	30	4/11/02	40	26	12
	30	4/18/02	24	18	15
	30	4/25/02	36	18	15
	30	4/25/02	36	18	9
Series	15	3/27/02	142	**482**	64
	15	4/03/02	137	103	48
	30	3/27/02	14	**101**	6
	30	4/03/02	26	15	8

Note that, on March 27, 2002, particle counts for sand effluents were actually higher (bold) than that for incoming secondary effluents. Table 3 shows that the particle counts for the two particle sizes were consistently lower for cloth media filter effluents than that for the sand filter effluents.

Figure 3 shows a graphical representation of particle sizes for each of the secondary effluent, the sand filter effluent, and the cloth media filter effluent. A lower particle size limit of 10 µm was chosen as particles greater than 10 µm are of primary concern when the effectiveness of UV radiation is in question. Therefore, particles less than 10 microns were not considered. Although this is one days worth of data (4/11/02), it is representative of distributions seen throughout the testing and demonstrates that particle counts for each particle size were routinely lower for the cloth media filter.

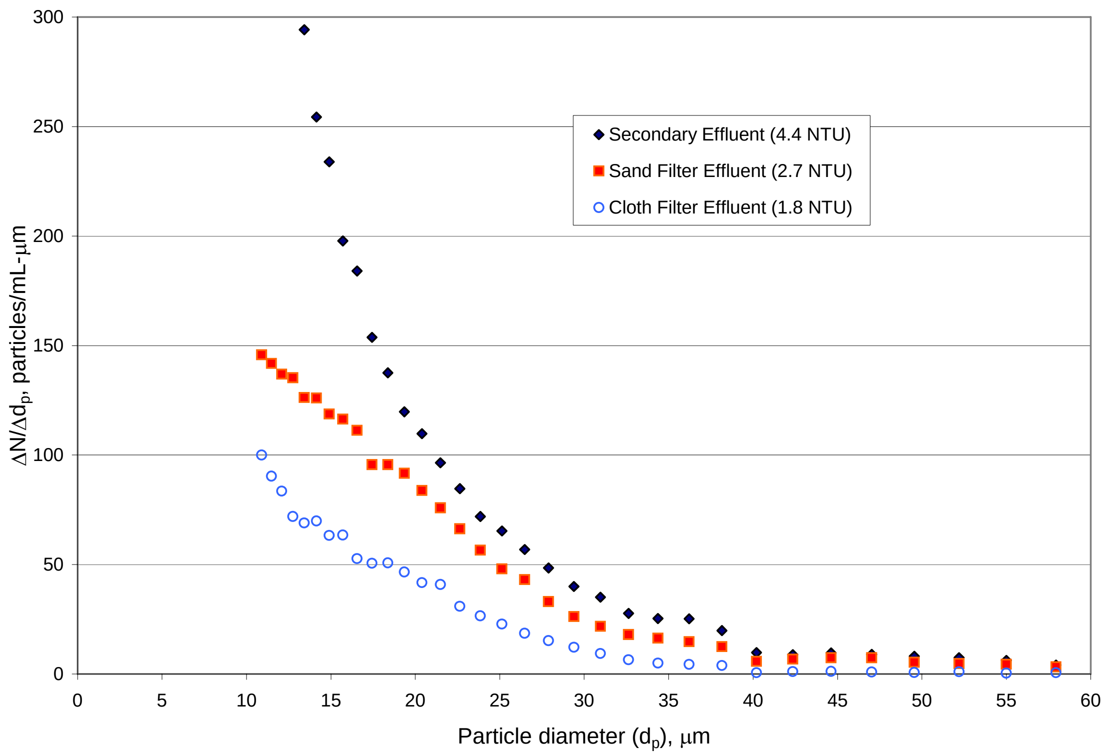

Figure 3 . Particle Size Comparison in Parallel Operation

UV Results

UV tests using Carollo Engineers' collimated beam apparatus were undertaken in accordance to the protocol established in the introductory section. Samples were irradiated and then sent to Babcock Laboratory (Riverside, California) for analysis for Total Coliform.

Initially, samples were to be analyzed using a 5-day fermentation test, used by the laboratory for all SDMWD water samples. However, the laboratory was limited in the number of samples that they could process by this method. As a result, it was decided to determine total coliform levels using an alternative method (Quanti-tray 2000) for total coliform quantification. Unfortunately, analysis by this method later was found to be troublesome and, ultimately, the laboratory was asked to use the 5-day fermentation test and agreed to process more samples than originally proposed. Because of this, reliable UV data is limited to the final weeks of testing.

Data obtained from samples analyzed with the 5-day fermentation method by Babcock Labs is summarized in Table 4. Data for the cloth media filter effluent shows that inactivation in order to meet the 2.2 MPN/100 ml limit can be achieved at the doses available in the RIX UV channels (~140 mJ/cm2). However, total coliform data for the sand filter effluent showed some variability and that inactivation occurred, in general, at much higher doses.

Table 4 . Total Coliform vs. UV Dose

	Sand Filter		**Cloth Media Filter**	
Date	**Dose (mJ/cm^2)**	**Total Coliform (MPN/100 ml)**	**Dose (mJ/cm^2)**	**Total Coliform (MPN/100 mL)**
4/25/02	72.9	>23.0	71.4	<1.1
4/25/02	120.8	6.9	118.8	1.1
4/25/02	168.1	3.6	168.7	<1.1
4/25/02	200.6	>23.0	203.7	<1.1
5/1/02	78	<1.1	25	1.1
5/1/02	130	>23.0	76	<1.1
5/1/02	181	>23.0	127	<1.1
5/1/02	183	1.1	182	<1.1
5/1/02	204	23	202	<1.1

Interestingly, the particle size distribution for the water samples on April 25, 2002 showed that the particle size distribution for sand filters and the cloth media filter effluents were essentially the same. On this date, the sand filter washers were optimized (air flow rates) and 20 ppm of alum was added. However, it was found throughout the studies that the sand filter often passed very large particles that were visible to the eye. These large particles could potentially lead to the results above in Table 4.

Although no particle size data is available for May 1, it is clear that sand filter effluent was not easily disinfected. It has been demonstrated that cloth media filter effluents were lower in overall particle counts when compared to that coming from the sand filter. Therefore, it can be presumed that the UV data from May 1, 2002 further suggests that size of particles affects UV disinfection.

Conclusion

The aim of this study was to determine the effectiveness of the AquaDisk® cloth media filter for the treatment of secondary effluent at the RIX site in order to either polish the sand filter effluent or to increase the capacity of the RIX facility. Furthermore, it was desired to determine the effect of particles on UV disinfection, given the recent violations of discharge limits on Total Coliform. Secondary effluents and filtered secondary effluents at the RIX facility were analyzed for particle size distribution and irradiated with a collimated beam over a two-month period. From the data presented in the previous sections, the following observations were drawn.

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The cloth media filter consistently out-performed the sand filter with respect to particle removal. Limited additional particle removal was found when operating the two filters in series. Particle size appears to have a significant impact on the ability of UV to inactivate total coliform. UV data showed that the required inactivation could be accomplished with the cloth media filter effluent over a variety of UV doses, while the required inactivation was highly variable and unreliable using the sand filter effluent. In summary, cloth media enhances UV disinfection through particle size reduction.

References

1. Carollo Engineers (July 2002), "AquaDisk® Pilot Test Summary", San Bernardino Municipal Water Department, RIX Facility.