Cloth media filter retrofit of sand filters increases filtration capacity

Performance test results at three wastewater treatment plants in the United States demonstrate that cloth media filters can consistently achieve reuse quality effluent. Authors **Robert C. Batek, PE**; **Hui Lin, PE**, **Peter G. Baumann, PE**, and **Terry Reid, PE** of the US company Aqua-Aerobics Systems, Inc. (Loves Park, Illinois) explain.

Until the early 1990s, granular media filters had been used almost exclusively for tertiary treatment in wastewater plants. In 1991, cloth media filtration technology was introduced to the United States and since then has made improvements in design, manufacture, application and performance. These improvements have resulted in widespread acceptance of cloth media filtration in a variety of mechanical configurations for wastewater treatment applications, including reuse. The cloth filtration medium used in AquaDiamond® cloth media filters provides reuse quality effluent of ≤5.0 mg/l TSS and ≤2.0 NTU turbidity.

AquaDiamond filters installed in existing traveling bridge sand filter basins were evaluated and successfully tested in three United States wastewater treatment plants. Conversion to the cloth media filters increased the flow capacity of the existing sand filter basins by two to three times in all three plants. Cloth media technology also demonstrated the capability to accept influent solids concentrations up to 171 mg/L under certain flow conditions while remaining in compliance. The ability to achieve high flow and influent solids concentrations in the existing basins reduced site space and construction costs.

Recent innovations in filtration technology have resulted in the development of cloth media filters that are capable of achieving high solids removal efficiencies at significantly increased hydraulic loading rates when compared to traditional sand media filters.

The principles of cloth media filtration are similar to sand media, but the mechanisms used to achieve performance objectives differ. Woven pile fabric media removes very fine particulate matter that does not settle to the tank bottom. The depth of the woven pile fabric creates a tortuous flow path which enables additional particle capture. As flow passes through the cloth media, solids are retained on and within the cloth fibers, forming a solids separation mat that provides an additional filter layer that enhances filtration. As solids deposit on the media, the pressure differential increases. Once the water level reaches an operator-defined set point, the PLC microprocessor automatically initiates a backwashing process. During backwash, a suction manifold removes excess accumulated solids from the media.

Recent innovations have resulted in the development of cloth media filters that are capable of achieving high solids removal efficiencies at significantly increased hydraulic loading rates when compared to traditional sand media filters.

The AquaDiamond filter is specifically designed for retrofit applications in existing sand filter beds. Long laterals supporting pile media are suited for converting rectangular basins into cloth media diamond filtration units. Horizontal rows of diamond-shaped laterals are mounted on the basin bottom. The application of cloth media produces a greater surface area and, combined with substantially higher flux rates, results in a significant increase in filtration capacity while accommodating the existing plant's hydraulic profile and civil structures. In Table 1, comparisons between AquaDiamond filters, in equivalent sized basins, to shallow bed traveling bridge sand filter are shown. Table 1 demonstrates that an AquaDiamond filter

Figure 2 – DCT AquaDiamond Filter Performance Test (04.12.09 – 21.01.10)

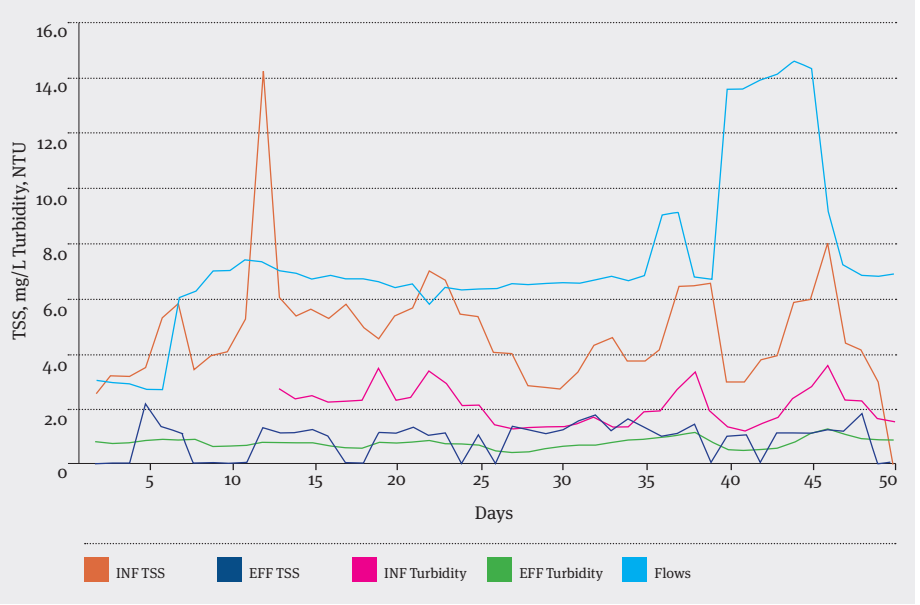

Table 1

Filtration System	Traveling Bridge Sand Filter	AquaDiamond Cloth Media Filter
Model	4.9x28.7	1680
Filter Bed Size	4.9 m (16 ft) x 28.7 m (94 ft)	4.9 m (16 ft) x 28.7 m (94 ft)
Available Filtration Area(m2)	164	238
Average Design Flux Rate (m/h)	5 (2 gpm/ft2)	8 (3.25 gpm/ ft2)
Average Design Flow (m3/d)	15,688	45,600
Peak Design Flux Rate (m/h)	12 (5 gpm/ ft2)	16 (6.5 gpm/ ft2)
Peak Design Flow (m3/d)	39,220	91,200
Solid Loading Rate (kg/m2/d)	5.9	8.6

Comparisons between shallow bed Traveling Bridge Sand Filters and AquaDiamond® Cloth Media Filters in equivalent size basins.

Table 2

Plant Name	Fox Metro WRF	TRA CRWS	D.C. Tillman WRP
Plant Design Average Flow (m3/d)	158,970 (42 MGD)	613,170 (162 MGD)	302,800 (80 MGD)
Plant Design Peak Flow (m3/d)	321,725 (85 MGD)	1,532,925 (405 MGD)	454,200 (120 MGD)
Plant Established	1920	1959	1985
Total Number of Basins Retrofitted with AquaDiamond Cloth Media Model 1680 Filter Units	6	6	8
Cloth Media Average Flow (m3/d)	272,160 (72 MGD)	272,160 (72 MGD)	362,880 (96 MGD)
Cloth Media Peak Flow (m3/d)	544,320 (144 MGD)	544,320 (144 MGD)	725,760 (192 MGD)
Discharge and Reuse Details	Fox River	Trinity River, Las Colinas Canals, numerous area golf courses	Los Angeles River, plant treatment processes, Japanese Garden, Wildlife and Balboa Recreation Lakes

Plant Details and Total Current AquaDiamond Filters in Operation

possesses significantly higher hydraulic and solids loading capabilities in a shorter filter size than does a traveling bridge sand filter.

Shallow Bed Traveling Bridge Sand Filter

The low-head, shallow-bed, traveling bridge sand filter is a continuous rapid-rate down flow filter. Each filter bed consists of a series of individual parallel filter cells, which contain sand media supported by a porous plate underdrain system. Since 1970, this type filter has become an efficient means of reducing turbidity and suspended solids in advanced municipal and industrial wastewater treatment processes worldwide.

The long-term reliability of the low-head filter technology depends heavily on porous plate and underdrain support system integrity. Caulking between the plates tends to deteriorate, resulting in media loss and short-circuiting. Other issues such as diminished hydraulic capacity and excessive backwash rates may occur. These issues can lead to deterioration in operational efficiency requiring excessive maintenance and can increase the inability to consistently meet discharge requirements. In addition, ongoing rehabilitation and media replacement require substantial capital and O&M investment.

Wastewater treatment facilities test cloth media filters

Three wastewater treatment facilities that were faced with failing traveling bridge sand filters and a need for expanded flow capacity are examined in this article. They are the Fox Metro Water Reclamation District plant (FMWRP) (Chicago suburb of Aurora, IL); the Trinity River Authority of Texas (TRA) (Dallas/Fort Worth metropolitan area); and the Donald C. Tillman Water Reclamation Plant (DCTWRP) (the City of Los Angeles). All three facilities upgraded existing sand filters with cloth media filters. Photos of these plants appear in Figure 1.

All three plants had common challenges with their existing traveling bridge filters that had aged. Full system rehabilitation was required due to mechanical, structural, and performance degradation. Some filters required chemical enhancement as well as repeated shock chlorination to maintain acceptable filter performance. The TRA CRWS is facing an additional challenge that the plant will soon require another 378,000 m3/d (100 MGD) of filtration capacity. A summary of plant details and modifications can be found in Table 2.

Results and discussions

Shortly after installation, process performance tests were conducted to confirm compliance with the design specifications and contractual obligations. The testing protocols, approved by engineers and/or customers, were executed to test the filters' performance at specified operational conditions.

Performance test at Fox Metro WRF: Field performance testing was conducted at Fox Metro WRF from July 4 to July 24 of 2007 on two of its existing six AquaDiamond filters. The primary purpose of the field performance testing was to verify if the specified effluent requirements could be reliably met. The anticipated performance requirements are listed in Table 3.

Table 4 includes influent and effluent TSS concentration, flow rate, and backwash rate data collected throughout the test period. Target effluent TSS conditions were achieved during the entire test period. Upstream conditions on Days 13, 14, 15, and 17 occurred in which solids carryover from the secondary clarifiers greatly exceeded the 30-mg/l design maximum. Influent TSS concentrations varied from 47 to 171 mg/l on these days. On Day 14, the 15-mg/l daily design average was exceeded with a 25.3 mg/l average. Daily average effluent TSS concentrations averaged between 2.2 and 5.2 mg/l. remaining within the permitted 12-mg/l limit. During these four days of upset conditions, the backwash water volume varied from 0.49 to 1.41 percent of the influent flow.

Performance test at TRA Central Regional Wastewater System (CRWS): Field performance testing was conducted at TRA CRWS from February 11 to February 17, 2008 on one of its six existing AquaDiamond filters. Targeted performance requirements are listed in Table 5. During the first three days, the peak flow and/ or peak influent TSS concentrations were simulated for two hours daily. Elevated influent solids simulation was achieved by adding concentrated MLSS from the plant's Returned Activated Sludge (RAS) line. Daily influent and filtrate composite samples were collected and tested at the plant's analytical lab to determine TSS values.

Table 6 includes influent and effluent TSS concentrations, flow rate, and backwash rate data collected during the test. The average effluent TSS objective of 5 mg/l was met while maintaining less than 3 percent backwash rate during the normal operational conditions.

Table 7 shows TSS concentration, flow rate, and backwash rate data collected during simulated two hour peak flow and/or TSS concentration operational conditions. The

Table 3

Parameter	Influent	Effluent
TSS (mg/l)	15	12
	30	-

Fox Metro WRF AquaDiamond Filter's Performance Requirements

Table 5

Parameter	Influent	Effluent
TSS (mg/l)	15	5
	30	15
Backwash rate limit, % of throughput based on influent filter TSS	15 mg/l 24 mg/l	3% 6%

AquaDiamond Filter's Performance Requirements for TRA CRWS

Table 8

Parameter	Influent	Effluent
Turbidity	1-10 NTU	2 NTU
TSS (mg/l)	10 Average	-
	17.6 Maximum	-

DCTWRP AquaDiamond® Filter's Performance Requirements

Figure 1. Retrofit of Cloth Media AquaDiamond Filter in Existing Sand Filter Basin (a) Fox Metro WRF (6) Model 1680 Units; (b) TRA Central, Dallas, TX (6) Model 1680 Units; (c) Donald C. Tillman Water Reclamation Plant, Los Angeles, CA, (8) Model 1680 Units.

average 15-mg/l effluent TSS objective was met during peak flows and influent TSS concentrations. Influent solids were as high as 58.90 mg/l while maintaining a backwash rate well below 6 percent of filter flow throughput during high flow and solids test simulation.

Performance test at Donald C. Tillman Water Reclamation Plant (DCTWRP): Field performance testing was conducted at the DCTWRP from December 4, 2009 to January 21, 2010 to evaluate the performance of the AquaDiamond filters. Filter performance was evaluated on four of eight filters currently installed. At design flow rates, the filters are designed to achieve Title 22 California Department of Public Health Water Recycling Criteria where a daily average effluent turbidity must not exceed 2 NTU while influent filter turbidity values may range from 0 – 10 NTU. The specifications also required the filter units to run without continuous backwashing or overflowing during average influent TSS concentrations of up to 10 mg/l and maximum TSS concentrations of 17.6 mg/l. The anticipated performance requirements are listed in Table 8.

> The AquaDiamond filter is specifically designed for retrofit applications in existing sand filter beds.

Figure 2 shows the data provided by DCTWRP as part of the performance evaluation. Turbidity values never exceeded the 2 NTU daily average Title 22 requirements. From a TSS removal standpoint, influent TSS values varied between 2.4 and 14.2 mg/l while filter effluent

TSS concentrations were consistently below 2 mg/l.

DCTWRP staff did not report any continuous backwash and overflowing. Daily backwash flow produced during this period varied between 0.04 and 0.45 percent while effluent solids varied between 1.0 and 3.7 mg/l.

Conclusions

Results generated during the three evaluations indicate a 240 percent average increase in treatment capacities by cloth media filtration technology while exhibiting comparable solids removal rates at design flow with an improved ability to achieve elevated performance during high solids loading events.

Results demonstrate that the cloth media filters are able to consistently achieve reuse quality effluent of ≤5 mg/L TSS and/or ≤2 NTU turbidity at the designed hydraulic conditions of 45,360 m^3/d (12 MGD) per filter average flow and 90,720 m^3/d (24 MGD) per filter peak flow and filter influent TSS concentrations ranging from 10 to 30 mg/L. During the Fox Metro study, the filtration system experienced conditions with a maximum influent TSS of 171 mg/L. The test results demonstrate that the filters met the ≤5 mg/L effluent TSS objective under this "upset" condition, and it quickly recovered after influent returned to normal TSS values. High flow and solids conditions were simulated at TRA CRWS with influent solids up to 59 mg/l. Filtered effluent solids during both these plants' high influent solids conditions were low and within permit levels. Title 22 reuse quality water was achieved at D.C. Tillman WRP during the entire test period. The average daily backwash rates for all three plants evaluated were generally less than 2.5 percent of the forward flow during 24 hour tests.

References

P. B. Baumann, P.E.; C. Kieffer; T. Morrall; R. Bauer, P.E., *Fox Metro Water Reclamation District Solves Filtration Problem With Innovative AquaDiamond® Cloth Media Filter*, WEFTEC 2006, Dallas, Texas.

H. Lin, P.E., Daniel J. Binder, Lloyd W. Johnson, MPD, P.E., *Effect of Particle Removal by OptiFiber® PA-13 Nylon Pile Media on Particle Size Distribution and Correlation between Turbidity and Total Suspended Solids*, WEFTEC 2008, Chicago, Illinois.

J.E. Caffey, P.E, *Performance Testing of High Peak Flow Cloth Media Retrofit of Traveling Bridge Filters*, Texas Water 2008, San Antonio, Texas.

Fox Metro Water Reclamation District 2010, Oswego, Illinois, viewed 10 June, 2011, http://foxmetro.dst.il.us.

Trinity River Authority of Texas 2010, Arlington, Texas, viewed 10 June, 2011, http://www.trinityra.org/.

City of Los Angeles – Department of Public Works 2011 – LA Sewers Donald C. Tillman Water Reclamation Plant, Los Angeles, California, viewed 10 June, 2011, http://lasewers.org/treatment_plants/tillman/.

Los Angeles City – Department of Public Works 2010 – Bureau of Engineering, Los Angeles, California, viewed 10 June, 2011, http://eng.lacity.org/.

Table 4

Day	Filter Flow (m3/d)		Influent TSS (mg/l)		Average Effluent TSS (mg/l)	Backwash Rate (% of Forward Flow)
	Max	Ave	Max	Ave		
1	59,500	53,785	11	9.8	2.2	0.63
2	55,526	42,506	10	6.9	2.7	0.56
3	48,448	39,705	12	6.8	3.5	0.56
4	56,132	40,462	12	6.2	2.0	0.50
5	51,362	36,752	12	6.5	2.4	0.60
6	46,101	36,336	10	4.9	2.9	0.56
7	46,896	37,396	11	6.8	2.7	0.51
8	55,375	39,478	9	4.8	2.2	0.80
9	46,063	36,790	9	6.2	2.8	0.43
10	44,436	36,336	8	4.7	2.5	0.51
11	50,719	39,856	6	4.4	1.9	0.50
12	51,060	38,645	8	4.5	1.9	0.48
13	68,206	41,484	106	14.3	3.4	1.17
14	69,493	58,819	171	25.3	5.2	1.41
15	67,600	53,217	110	14.4	2.2	0.68
16	63,437	49,962	8	5.7	2.2	0.40
17	68,887	52,990	47	7.6	2.4	0.49
18	56,056	43,868	7	4.8	2.5	0.55
19	48,864	40,462	10	5.8	2.8	0.49
20	45,042	38,039	10	6.6	4.3	0.56
21	48,978	40,613	15	6.2	3.0	0.53

Process Performance Test -Fox Metro WRF (04-July-07 to 24-July-07)

Table 6

Date	Influent Flow rate (m3/d)	Average Influent TSS (mg/l)	Average Effluent TSS (mg/l)	Backwash Rate (% of Forward Flow)
2/11	49,707	10.15	1.71	1.69
2/12	28,388	9.63	3.00	1.63
2/13	26,498	12.56	1.60	2.23
2/14	46,532	17.65	2.00	2.02
2/15	47,174	14.00	2.00	1.63
2/16	47,212	15.00	1.00	1.67
2/17	40,711	15.00	1.00	1.56

TRA CRWS TSS Removal and Backwash Rate under Normal Operational Conditions

Table 7

Test Run	Date	Test Period, Time of Day	Influent Flow rate (m^3/d)	Average Influent TSS (mg/l)	Average Effluent TSS (mg/l)	Backwash Rate (% of Forward Flow)
1	2/12	9:31-11:32	86,638	23.72	9.50	2.74
2	2/12	12:30-14:30	68,191	29.05	5.00	3.41
3	2/12	17:01-15:00	85,655	10.00	1.00	2.08
4	2/13	9:00-11:00	54,659	27.80	1.50	3.27
5	2/13	13:00-15:00	42,790	58.90	0.62	5.76
6	2/13	15:30-17:32	87,772	13.00	1.62	2.44
7	2/14	10:30-12:40	84,181	33.10	3.40	3.03

TRA CRWS TSS Removal and Backwash Rate under Operational Conditions with Simulated Peak Flows and/or TSS Concentrations