Performance Testing and Long Term Operations Demonstrate Successful Application of the Hydrotech Discfilter System for Stringent Effluent Phosphorus Limits

INTRODUCTION:

The North Attleborough, MA Wastewater Treatment Facility (WWTF) received a renewed discharge permit in 2007. Starting in 2013, the facility would be required to meet a monthly average effluent Total Phosphorus (TP) limit of 0.1 mg/L from April 1 through October 31. The WWTF planned for upgrades to the Biological Nutrient Removal (BNR) process, but also needed a tertiary treatment process to guarantee the stringent limit would be met. The facility hoped to be able to use some of the existing footprint and infrastructure for the new upgrades in order to minimize project cost and avoid the need to expand the facility footprint. Through an extensive technology evaluation process, the Hydrotech Discfilter system with upstream chemical pre-treatment was selected and installed for tertiary TP removal. The system was commissioned in the summer of 2013, and has proven to meet the design parameters through initial performance testing as well as continued long term operations.

BACKGROUND:

Treatment Technologies Evaluated

The North Attleborough, MA Department of Public Works collaborated with their local consulting engineer to evaluate viable tertiary treatment alternatives to meet the facility's needs. They considered a number of options, including conventional dual media filtration, high rate ballasted flocculation, two-stage deep bed sand filtration, ultra-filtration (UF) membranes, and woven cloth Hydrotech Discfilters. Initially, the evaluation was focused on a 2-stage approach to TP removal. Accordingly, pilot tests for three 2-stage trains were conducted in July and August of 2009. The three configurations consisted of: 1) a two-stage deep bed upflow sand filter, 2) a ballasted flocculation system followed by a dual media filter, and 3) a Hydrotech Discfilter followed by a UF membrane. Samples were analyzed into and out of each stage of the three trains. The pilot efforts demonstrated that the first stage of each configuration was able to achieve the TP effluent target of ≤0.1 mg/L. Therefore, consideration of treatment technologies was refined to the ballasted flocculation and Hydrotech Discfilter technologies because of their small footprint and low overall cost to install, operate, and maintain.

Extended Pilot Testing of Short-Listed Technologies

The Discfilter was determined to be the low cost alternative and the preferred technology because of the straight-forward operation and maintenance. Due to the fact that this would be the first woven cloth filter system designed for such a stringent effluent TP target, a second round of piloting was conducted from late November 2010 to early January 2011. This round of testing included two treatment systems: 1) high rate ballasted flocculation, and 2) the Hydrotech Discfilter system. Both systems were tested at hydraulic loading rates equivalent to average and peak conditions, at inlet TP concentrations up to 1 mg/L, and under a "stress" condition of high inlet TSS concentration to simulate a

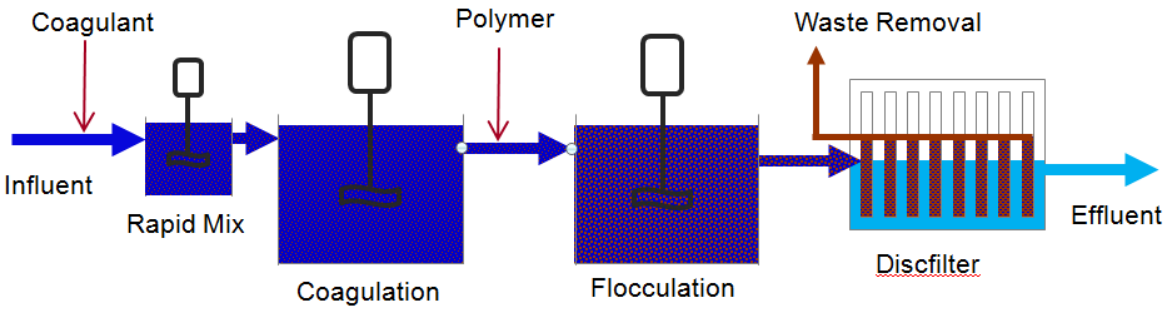
clarifier upset. Both systems performed well, proved the ability to meet the target effluent TP of ≤0.1 mg/L, and validated the data collected in the prior 2009 pilot study. Upon completion of the pilot, the Hydrotech Discfilter was selected for full-scale implementation. The system offered the benefits of lower life cycle cost, the ability to fit within the footprint of the existing traveling bridge filter (TBF) building and the facility's hydraulic profile, and the characteristic of being easy to operate and maintain.

PROCESS DESCRIPTION:

Chemical Pre-Treatment and Discfilter Process

At BNR facilities such as North Attleborough, it is not unusual for effluent from the BNR process to reach TP levels below 0.5 mg/L. However, to reach levels below 0.1 mg/L typically requires an added treatment step at the tertiary stage. The TP is present in two forms: 1) phosphorus that is bound in solid/particulate form within the TSS and 2) soluble phosphorus. The Hydrotech Discfilter uses a polyester cloth with nominal 10 micron openings in order to remove fine particles from the water, but a a significant portion (up to 50% or more) of the TP exists in soluble form and must be precipitated in order to be effectively removed by the filter media. In order to do this, a chemical pre-treatment process is implemented upstream (see Figure 1). Coagulant is added and mixed with the influent flow stream in order to perform the chemical precipitation. The coagulant is dosed prior to a short (typically <1 min retention time) rapid mix zone. The flow passes from the rapid mix zone to a coagulation zone of several minutes. Polymer is added to the flow as it leaves the coagulation zone and enters a flocculation zone of several minutes retention time. The polymer acts to form particles that are of adequate size and strength to be removed by the filter. Once the water has passed through the chemical pre-treatment process and filter system, both particulate and soluble phosphorus are reduced.

Figure 1: Chemical Pre-Treatment and Discfilter Process Schematic

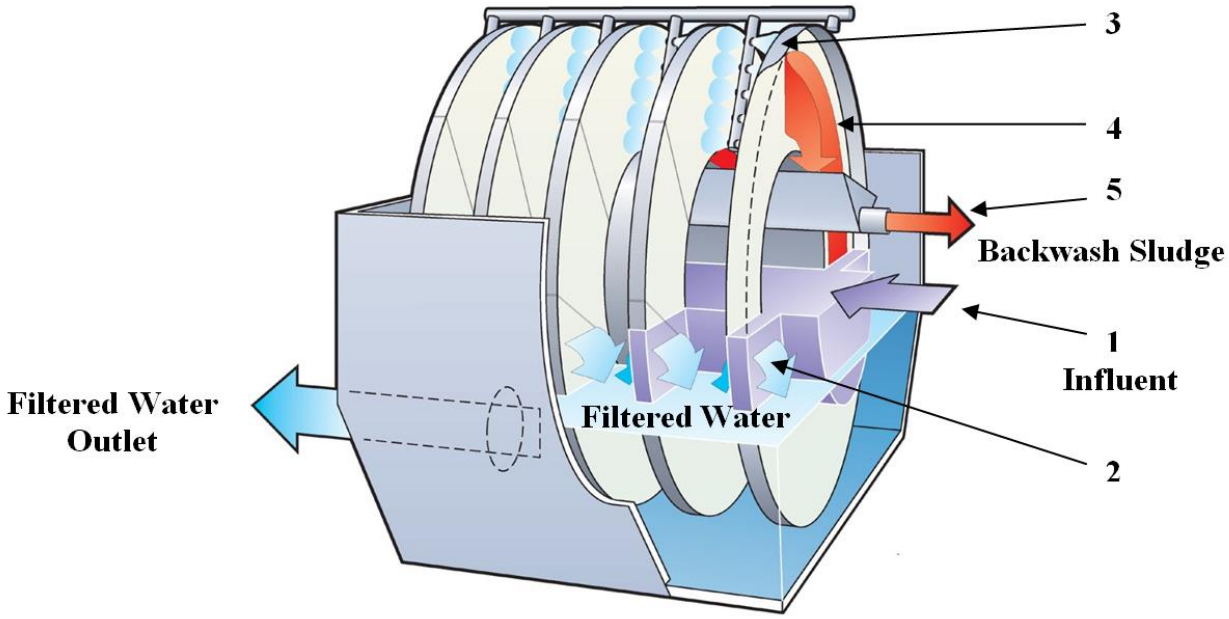


Hydrotech Discfilter Technology

The Hydrotech Discfilter is an innovative technology that allows for a high filtration capacity within a small physical footprint. Each unit consists of a machine chassis, a chamber to collect the influent, a drum to support the discs and direct influent flow into the discs, discs with filter media on each side, a

drive motor to rotate the drum during backwashing, a backwash pump, a backwash sludge collection trough, and water level instrumentation. A control system monitors the status of motors and instruments in order to automatically operate the unit and provide status and alarm signals to the operators. The automatic operation of the Hydrotech Discfilter consists of several engineered components and process steps (see Figure 2).

Figure 2: Discfilter Operation



Influent (1) flows by gravity into the filter discs from the center drum. Solids are separated from the water by the filter media mounted on the two sides of the discs, which are partially submerged (2). With this arrangement, the solids are retained within the filter discs while only the clean water flows to the outside of the discs and into the collection tank. This allows for the effective removal of large solids and floatable material. The filtered water collection tank can be provided as an integral part of the stainless steel chassis, or the Discfilter unit can be provided as a "frame" type that can be placed into a separate collection tank or basin (such as concrete). The "frame" type is the version used at the North Attleborough WWTF, and the existing TBF basins are used as the filtered water collection tanks.

The difference in water level from inside to outside of the filter panels supplies the driving force for filtering. The inside to outside flow path prevents solids accumulation in the collection tank, reducing operation and maintenance costs. During normal operation, the discs remain static and solids collect on the inside of the filter panels, gradually impeding the water flow through the discs, thus increasing the inlet water level. The inlet water level is measured and monitored by the control system. When the water level reaches a set point, the backwash cycle is initiated. A pressurized spray from the nozzles (3) is directed onto the outside surface of the filter panels while the discs rotate. The spray passes through the openings in the filter media. At the same time, the drum and discs are rotated in order to move the dirty media into the path of the pressurized spray and to place clean media into the influent flow path to

continue filtering influent solids. As the discs rotate, the captured solids are washed off the inside surface of the media (4). The backwash water and the captured solids fall into the sludge collection trough located within the center drum and exit the filter through the backwash piping (5).

The inlet water level will drop as the backwash cycle introduces clean filter media into the flow path. Once the discs have been sufficiently cleaned, the backwash cycle will stop. The backwash cycle will begin again when the inlet water level increases again to the set point. The filtered effluent is the supply source for the backwash water, eliminating the need for a separate source of backwash water.

Hydrotech Discfilter System at the North Attleborough WWTF

The Hydrotech Discfilter system for the North Attleborough WWTF was designed to treat a peak hour flow of 17 MGD and an average day flow of 4.8 MGD while achieving an average effluent TP of ≤0.1 mg/L. Construction of the system was completed and commissioning occurred in the summer of 2013. Upstream of the filters are two mixing zone trains (see Figures 3 & 4) for the purpose of precipitating and flocculating the phosphorus from soluble to particulate form that can be captured and removed by the filters. Each train has 1 rapid mix zone (with 1 vertical shaft rapid mixer), followed by 3 coagulation/flocculation zones (each with 1 vertical shaft slow speed mixers). Coagulant is dosed upstream of the rapid mix zone, while polymer is dosed downstream of the first coagulation zone. The system includes six (6) of the model HSF2224-2F Hydrotech Discfilter units (see Figure 5). Four (4) of the units are considered “duty” and two (2) units are “redundant”. The system is monitored and controlled by an integrated instrumentation and control system.

Figures 3 & 4: Mixing Zones with Chemical Dosing Upstream of Discfilters

Figure 5: Hydrotech Discfilter Units Installed in Existing Filter Building

PERFORMANCE TESTING:

A seven day performance test was conducted from August 20 – 27, 2013 in order to demonstrate the system's compliance with the treatment objectives. The test included operating scenarios as close as possible to peak and average hydraulic loading rate (HLR) conditions. During the test period, flow to the WWTF was lower than the specified design criteria. In order to account for this, only 1 unit (for peak flow rate testing) or 2 units (for average flow rate testing) was placed in service during the test period. The system design provides 4 "duty" units, yielding a design peak flow of 4.25 MGD and design average flow of 1.2 MGD per discfilter unit. Flow measurements were recorded from the facility's effluent flow meter in order to confirm the HLR during the test.

Automatic composite samplers were located at the clarifier effluent collection box and at the Discfilter system effluent channel in order to sample filter system influent and effluent characteristics. Each sampler contained a single sample bottle and was programmed to collect a sample into the bottle at 15 minute intervals. The samples were collected and provided to a local independent certified lab for analysis. The lab utilized Standard Methods 4500P-E in order to determine the TP concentration of each sample.

Coagulant and polymer were dosed in the mixing zones upstream of the filters during the performance test. The chemical addition was flow paced based on results from the effluent flow meter. The results for the flow meter were averaged over 60 minutes in order to smooth out rapid flow fluctuations and provide a relatively steady chemical dosage. Ferric chloride ($FeCl_3$, 38% wt./wt. active, S.G. = 1.43) was used for coagulation and a proprietary polymer was used for flocculation. The ferric chloride was dosed at 28 ppm and the polymer was dosed at 0.6 ppm throughout the test period.

The test began on August 20, 2013 at 7:00 AM local time. For the first three days of the study, only one unit was operated in order to simulate peak HLR conditions. The remaining four days of the test, two units were operated in order to simulate average HLR conditions. At 7:00 AM each day, adjustments were made for which units would be operated for that respective test day. Table 1 indicates which units were operated each day and the flow rate values (maximum and average) recorded each day.

Table 1 : Performance Test Data

Test Day Start	Unit(s) in service	Maximum Effluent Flow (MGD)	Average Effluent Flow (MGD)	Maximum Effluent Flow per unit (MGD)	Average Effluent Flow per unit (MGD)	Influent TP (mg/L)	Effluent TP (mg/L) **Limit = 0.1**	TP Removal Efficiency (%)
8/21/2013	#1	4.94	2.79	4.94*	2.79	0.114	0.018	84
8/22/2013	#2	8.00	2.79	8.00*	2.79	0.136	0.027	80
8/23/2016	#3	3.58	2.84	3.58	2.84	0.127	0.021	83
8/24/2016	#1 & #4	4.39	2.90	2.20*	1.45*	0.149	0.019	87
8/25/2016	#1 & #2	4.74	2.83	2.37*	1.42*	0.155	0.022	86
8/26/2016	#2 & #3	4.62	2.85	2.31*	1.43*	0.136	0.023	83
8/27/2016	#3 & #4	4.29	2.91	2.15*	1.46*	0.141	0.026	82
					Average:	0.137	**0.022**	84

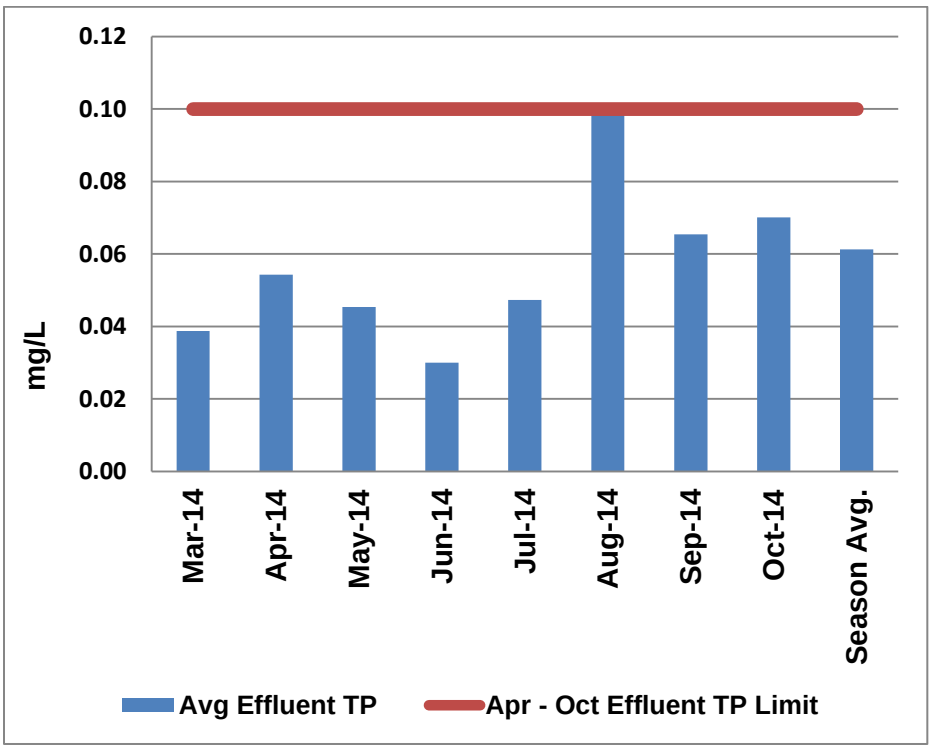
*Flow conditions per unit were higher than design.

Although the flow conditions during the test period were often higher than the specified design criteria per discfilter unit, the system was able to provide the required effluent quality and achieve excellent TP removal, thus proving that the system could meet the design targets even at higher HLR conditions. During the test, the upstream BNR process was operating well and producing TP concentrations of approximately 0.14 mg/L, close to the required limit of ≤0.1 mg/L. The Hydrotech Discfilter system operated as designed and intended. Despite the relatively low influent TP concentrations received from the upstream BNR process, the system was still able to achieve TP removal of >80% and provide an average effluent TP of 0.02 mg/L, meeting the target of reducing the facility effluent TP to ≤0.1 mg/L.

LONG TERM OPERATION:

In April of 2014, the facility entered the first full season of operation to meet the more stringent TP requirement. The facility operates the Discfilters year-round for effluent TSS polishing, but only operates the chemical pre-treatment system as required to meet the WWTF's TP limits. In March 2014, the facility began dosing chemicals and operating the pre-treatment system in conjunction with the discfilters in preparation for the lower limit that would be required starting in April. The effluent TP averaged 0.04 mg/L during the month of March. For the period from April 1 through October 31, 2014, the WWTF effluent TP averaged 0.06 mg/L; below the permit limit of 0.1 mg/L (see Figure 6). The system continues to operate and enable the WWTF to meet permit limits.

Figure 6: Effluent Average TP results



CONCLUSION:

The Hydrotech Discfilter installation was the first known cloth media filter installation specifically designed to achieve effluent TP of ≤0.1 mg/L. Through a detailed engineering review and two on-site pilot studies, the system was selected as the optimal solution for the site's needs. Specifically, the Hydrotech Discfilter system was able to conveniently fit within the existing facility footprint and hydraulic profile, while providing the benefit of convenient operation and maintenance. The process includes chemical pre-treatment to precipitate soluble phosphorus. The Hydrotech Discfilters remove the precipitated phosphorus as well as phosphorus bound in the TSS from the upstream BNR process. Since commissioning in 2013, the system has provided the site with continued outstanding performance and enabled the WWTF to successfully achieve the stringent effluent requirement of ≤0.1 mg/L TP.

Author:

Mark Stewart, Product Manager – Hydrotech Filtration

Veolia Water Technologies

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