Full Scale Implementation, Operation, and Performance of a Structured Sheet Media IFAS System

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ABSTRACT

This case study has shown that existing CAS facilities can be economically retrofitted with structured sheet media to achieve enhanced nitrification. Performance data collected for more than one year has confirmed that the structured sheet media IFAS system was able to consistently meet the ammonia discharge limits even in concurrent wet and winter weather (e.g. 7-9^{o}C at over three times design flow). The IFAS system has also proven to operate similarly to the prior CAS process and requires little attention from the operator. In the typical plug-flow structured sheet media IFAS system, tapered aeration with fine bubble diffusers was utilized to minimize filamentous growth, improve solids settleability, optimize kinetic rates, and provide energy savings. Additionally, as a benefit for the system installation, the rigid and stackable media blocks allowed for a simple retrofit of the existing aeration basin without the need for constructing baffle walls or media retention sieves.

KEYWORDS: Integrated Fixed-Film Activated Sludge (IFAS), Structured Sheet Media, Nitrification, Fine Bubble Diffusers, Full-Scale.

INTRODUCTION

Background

The Hopedale, MA wastewater treatment plant (WWTP) was originally designed as a Conventional Activated Sludge (CAS) plant to meet secondary BOD_5 and TSS treatment limits, with an average design flow of 0.588 mgd. New NH_3-N limits (Table 1) implemented in 1999 exceeded the original process design capability of the facility for consistent nitrification, especially during the winter months. By September 2005, the plant was under an EPA Administrative Order to address multiple violations of effluent ammonia limits as contained in their NPDES permit.

Table 1 Effluent ammonia limitations for Hopedale, MA wastewater treatment facility

Effluent Characteristics	Average Monthly Effluent Limit Concentration
NH_3-N (November 1 – April 30)	11 mg/L
NH_3-N (May 1 – May 31)	5 mg/L
NH_3-N (June 1 – October 31)	2 mg/L

Driven by the requirements of the Order, a comprehensive evaluation of the treatment facility was conducted which determined that the incorporation of an aerobic fixed-film system (e.g. IFAS) would be the most feasible alternative in terms of cost and process capability to bring the facility into compliance with the NH_3-N limits. Following a successful pilot study, structured sheet media IFAS was selected for the aeration basin upgrade to enhance cold winter nitrification.

Objectives

Structured sheet media has been increasingly recognized as a cost-effective solution for full scale IFAS applications (Ye et al., 2009, 2010-a&b); however, the implementation, operation, and performance of such systems in full scale have been less reported. This case study is intended to present typical installation methodology, discuss important operating parameters, and also evaluate process performance of a full scale structured sheet media IFAS system.

FULL SCALE PROCESS DESIGN OF STRUCTURED SHEET MEDIA IFAS SYSTEM

Description of Hopedale, PA WWTP Plant

The treatment process at the Hopedale, MA WWTP includes aerated grit removal for settling of heavy inorganic materials, aerobic secondary treatment for BOD reduction and ammonia conversion, secondary clarifiers for TSS removal and activated sludge collection, and an ultraviolet disinfection system (Figure 1). Figure 2 is the aerial photo of the Hopedale WWTP.

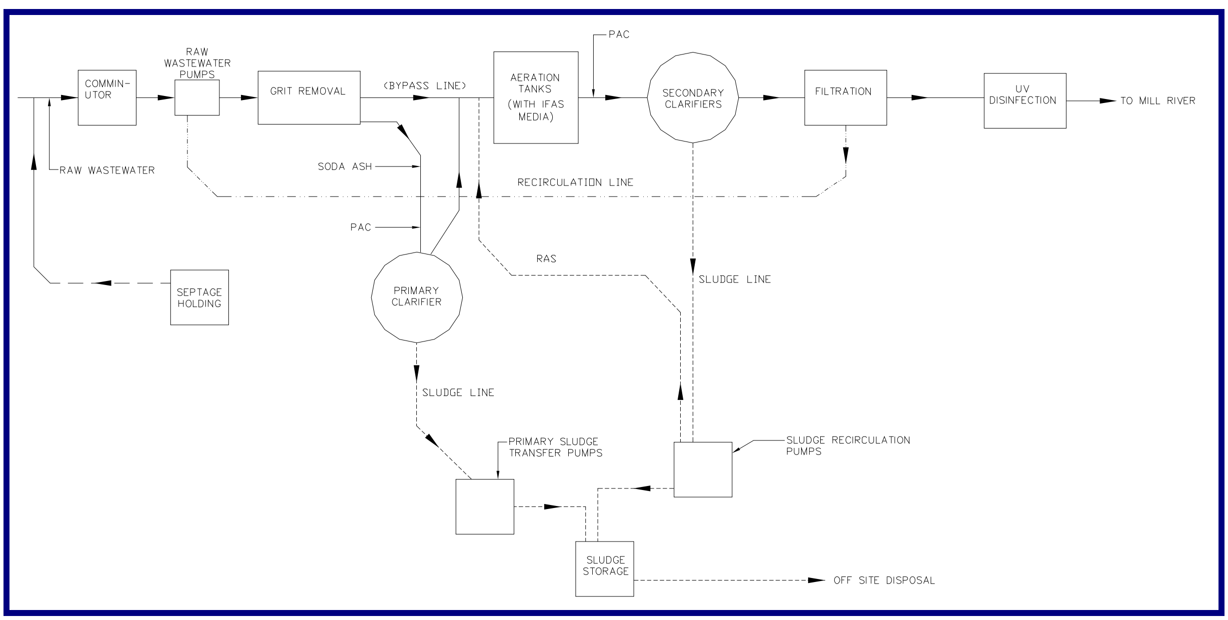


Figure 1 Process schematic of Hopedale, MA wastewater treatment facility

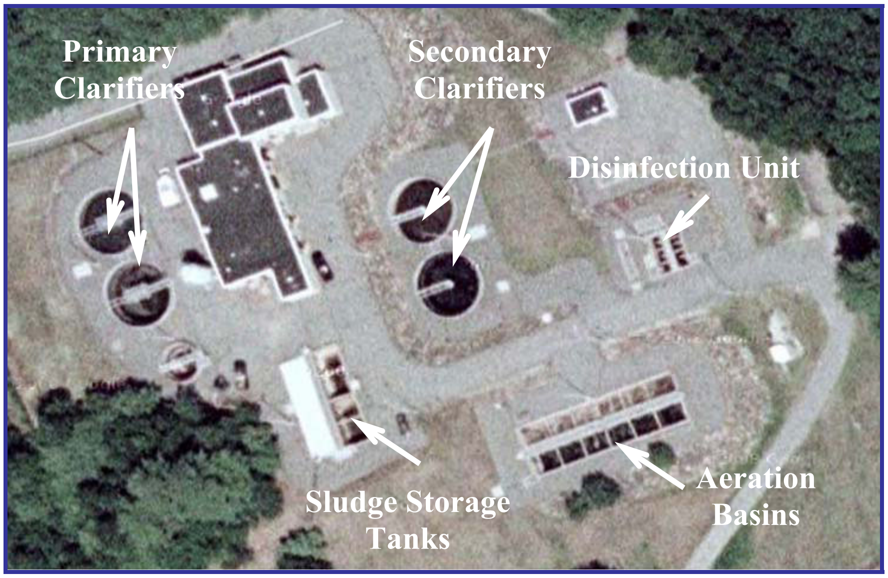


Figure 2 Aerial photo of Hopedale, MA wastewater treatment facility

Process Design

Process modeling with calibrated BioWin software determined that a retrofit consisting of approximately 25% structured sheet media fill in the existing aeration basins would provide sufficient media surface area for attached biomass growth to achieve the required ammonia limits during the winter time. Provisions for adding future media towers (e.g. due to capacity increase) were also considered in the process design to include properly configured fine bubble diffuser grids in the activated sludge area (in addition to the media fill area). In order to maximize the use of attached surface for nitrification, the discrete fixed media towers with downcomer regions between towers were positioned towards the outlets of the aeration basins, leaving only mixed liquor on the influent sides of the aeration basins for BOD removal. Figure 3 shows the IFAS media tower layout in the Hopedale, MA WWTP.

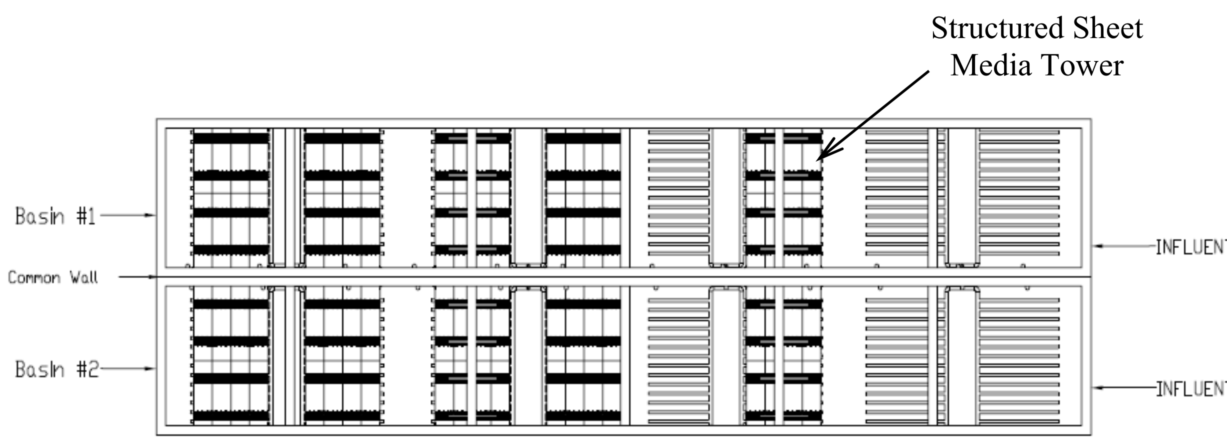
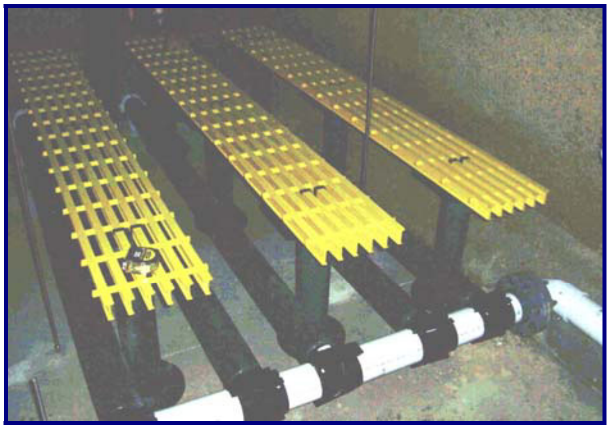


Figure 3 Hopedale, MA WWTP IFAS tower plan-view layout

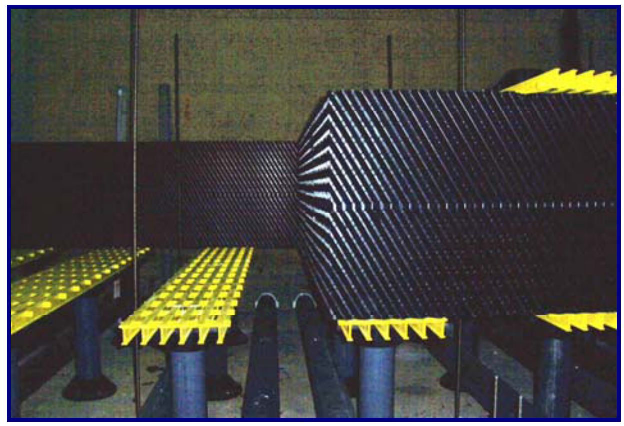
RESULTS AND DISCUSSIONS

Implementation of Structured Sheet Media IFAS System

The installation of a structured sheet media IFAS system involved the integration of media, media support and restraint systems, and in-basin aeration diffusers. Figure 4 identifies the typical construction sequence of the AccuFAS media towers, including diffuser and pier layout, media placement, and restraint system installation. The modular structured sheet media blocks (e.g. 2 ft wide × 2 ft high × 4 ft long) are lightweight, rigid, and stackable. They were hand-installed without the use of cranes or other expensive installation equipment. The layout of discrete media towers along the direction of the flow also provides for a process approaching plug-flow without the need for baffling.



(a) Installing diffusers and assembling piers and grating as media supports



(b) Placing structured sheet media modules

(d) Installing media restraint system

(d) Overview on the completed media towers

Figure 4 Construction sequence of AccuFAS media towers

The engineering of the structured sheet media IFAS system was intended to not only maximize the flow circulation through the media to provide intimate contact and sufficient scouring, but also to allow for convenient access to diffusers for easy maintenance. For example, the tubular membrane fine bubble diffusers were only placed below the media towers, but not in downcomer regions between media towers in order to facilitate airlift pumping and mixed liquor circulation through the media. The downcomer regions are typically 3.0-ft wide, providing access to aeration manifolds for diffuser maintenance (Figure 5). A typical bottom clearance space of 1.5 to 2.0-ft from the tank floor was maintained in order to move diffuser arms during service (Figure 6). The diffusers are typically mounted within 1.0-ft off the floor or as close to the basin floor as possible to prevent solids settling and buildup on the tank floor.

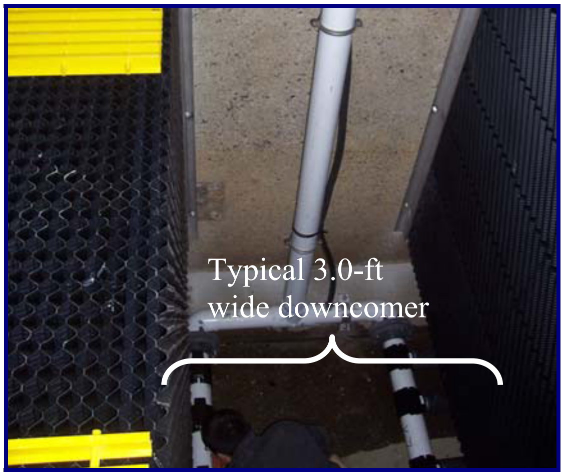


Figure 5 Downcomer region showing access to diffuser manifolds

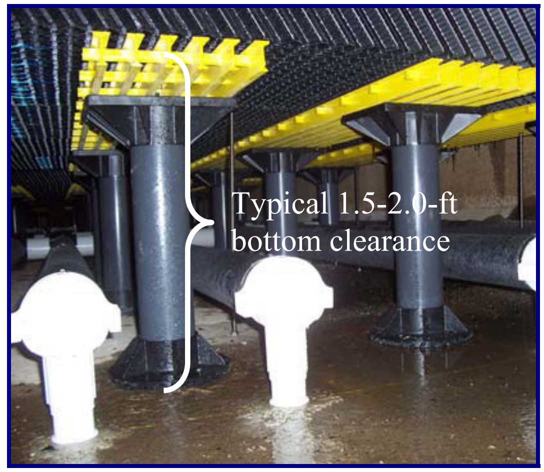


Figure 6 Bottom clearance of media towers showing diffuser ends

Operation of Structured Sheet Media IFAS System

Startup Procedures: The first IFAS train was started in the end of March, 2009 to handle the total plant flow while the second IFAS train was under construction. Before introducing mixed liquor or combined influent feed (also containing RAS) to the IFAS basin for startup, the tank floor was initially filled with about 1.0-ft clear water to check whether there were any leaking diffusers or aeration connections (Figure 6). Aeration was not started until the media towers were fully submerged with at least 8 inches of top water in order to avoid possible airlifting damage to the dry media packs. Figure 7 shows the submerged media system under aeration. White froth foaming was observed during the startup, primarily due to a low solids concentration and sludge age and it disappeared in about three (3) days as the process stabilized and solids built up.

The second IFAS train was not brought online until early August, 2009 although the installation was completed in May. The off-line IFAS basin was filled with the disinfected plant effluent in order to prevent UV degradation of the structured sheet media. In order to provide sufficient time for biological growth to be achieved within the second IFAS basin for the best nitrification performance during winter time, specific guidelines were established to determine the best start-up date, dictated by whichever event occurs first:

- At a time at least 30 days prior to the date when historical average wastewater temperatures drop to 15^{o}C;
- At a time in late summer when the wastewater temperature has dropped 2^{o}C less than the preceding summer average temperature;
- At a time when sustained hydraulic conditions reduce the HRT to less than 4.0 hours.

Figure 6 Diffuser under clear water testing during startup

Figure 7 Submerged media towers under aeration

Suspended Solids Concentration: A mixed liquor suspended solids (MLSS) concentration of 1,000-3000 mg/L was maintained in the aeration basins, which was similar to the previous activated sludge process (Figure 8). The critical suspended Solids Retention Time (SRT) curve (Figure 9) obtained during July to October with wastewater temperatures ranging from 15-20^oC indentified that a minimum MLSS concentration of approximately 1,250 mg/L should be maintained to achieve the effluent ammonia limit of 2.0 mg/L during summer.

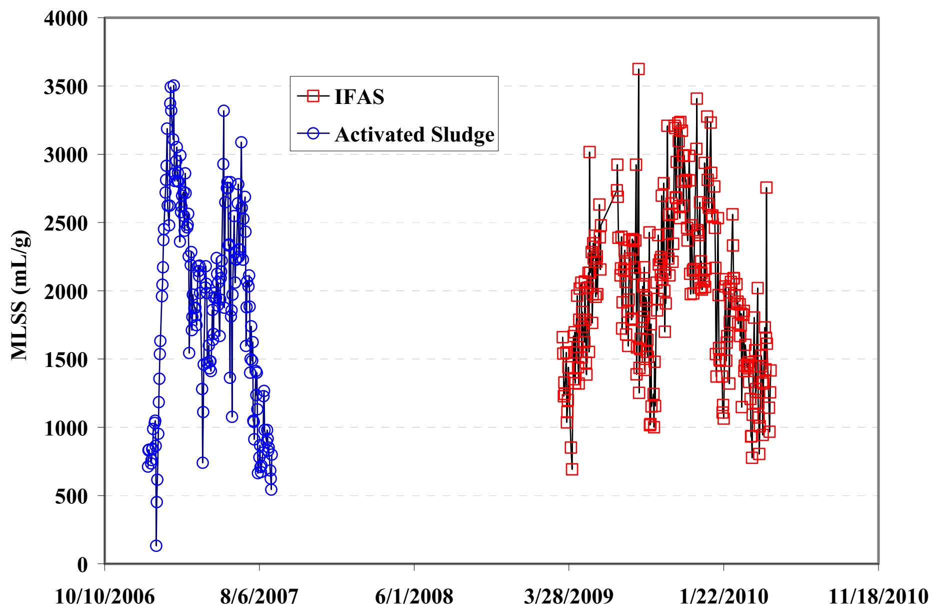


Figure 8 MLSS concentrations in the IFAS basins as compared to the activated sludge process in Hopedale, MA WWTP

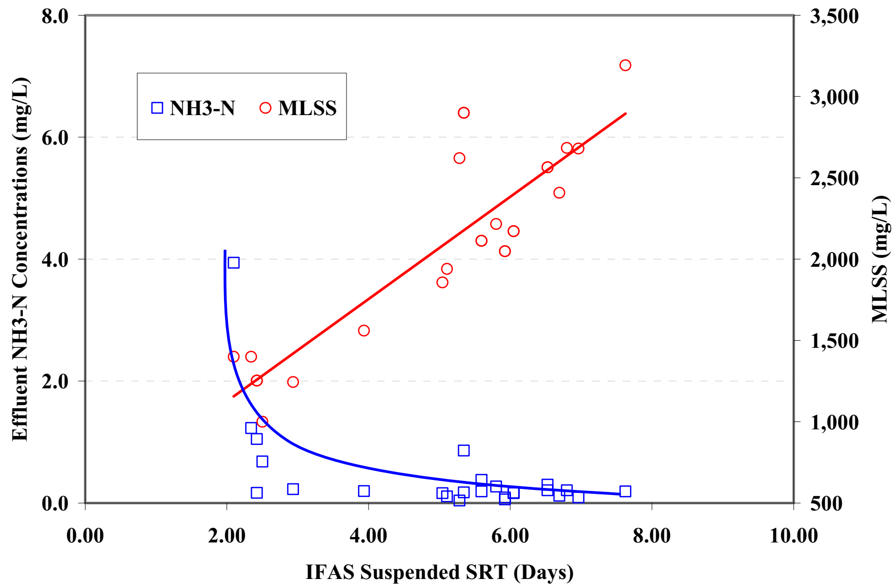


Figure 9 Relationship between MLSS, suspended SRT, and effluent ammonia concentrations in the IFAS system

<u>*Process Dissolved Oxygen (DO) Control*</u>*:* A DO concentration of 3.0-6.0 mg/L was typically maintained throughout the IFAS basin in order to provide sufficient aeration for both process and mixing requirements. A DO probe situated in the middle of the aeration basin transmits signals to the VFD controlled blowers to supply the appropriate volume of air to the diffuser system. The DO concentrations in the effluent channel of the aeration basins were also monitored to ensure adequate oxygen carry-over to the secondary clarifiers to prevent potential sludge bulking as a result of denitrification. Figure 10 shows the locations of the DO probes in the IFAS basin.

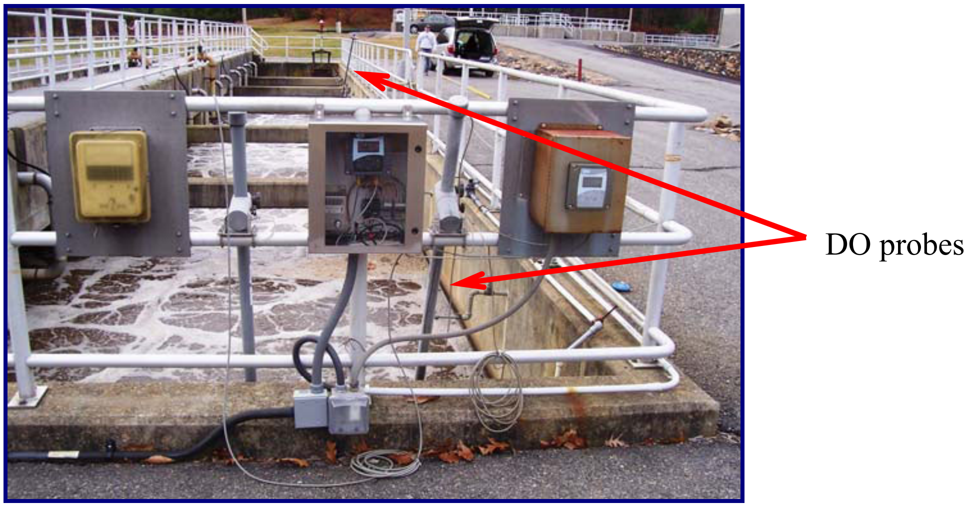


Figure 10 DO probes in the IFAS basin

During the early operation of the IFAS system, air valves were not regulated to taper aeration along the direction of the flow. This resulted in insufficient air supply to the high organic loads on the influent side of the IFAS basin and consequently caused the growth of filamentous microorganisms and sludge bulking in the clarifiers. The subsequent implementation of tapered aeration has improved the settling performance of the clarifiers and also the overall operation of the IFAS system. An increased DO profile along the length of the aeration basin was observed even at similar air flow rates and organic loads after tapered aeration was introduced (Figure 11), supporting tapered aeration was more efficient in air utilization than non-tapered uniform aeration. The tapered aeration has also resulted in scouring air flow rates of approximately 0.5 and 0.16 SCFM/ft^2-media plan view area for the first and last media towers, respectively, although the overall scouring air was about 0.4 SCFM/ft^2. This was equivalent to an approximately 20% reduction on the overall mixing aeration requirement when compared to the scouring air requirement for the first media tower.

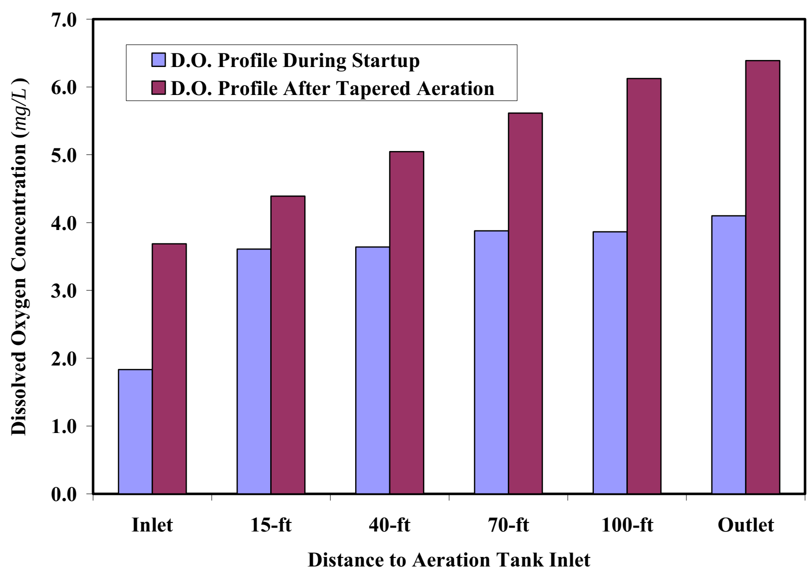


Figure 11 D.O. profiles along the length of the IFAS aeration basins at similar air flow rates and organic loads before and after tapered aeration

Performance of Structured Sheet Media IFAS System

Ammonia Removal: Figure 12 shows the nitrification performance of the structured sheet media IFAS system. The plant has been consistently in compliance with the ammonia limits since the IFAS upgrade even at winter wastewater temperatures as low as 7-9°C. Initial nitrifier acclimation during the startup period was slow due to the low wastewater temperatures (less than 15 °C) and also the "excessive" organic loads on the single IFAS train at a plant flow rate of 0.5-0.6 MGD. It took approximately two months before the single IFAS train achieved full nitrification as the water temperature rose to greater than 15°C and the plant flow dropped to about 0.4 mgd, close to the design flow per train (e.g. 0.294 MGD) in late May. This suggests that a minimum wastewater temperature of about 15°C will be desired for substantial nitrifier growth during startup of a structured sheet media IFAS system. However, once established, the nitrifying populations on media appeared to be able to sustain significant ammonia removal capacity even at wastewater temperatures less than 15°C.

During late July and early August of 2009, the plant identified both the hydraulic flow increases and the potential start of seasonal wastewater temperature decline and decided to bring the second IFAS train on line. The nitrifier acclimation on the second IFAS train took less than one week due to the optimal wastewater temperature (e.g. about 20^{o}C), resulting in essentially zero ammonia concentrations in the effluent from September to December even when the wastewater temperature dropped to below 15^{o}C. The quick acclimation process also helped maintain sufficient nitrifying population for the cold weather ammonia removal. During March, 2010, the plant experienced a historical flood event and the monthly average flow exceeded 1.0 MGD with a daily average flow of as high as 2.0 MGD. This resulted in significant suspended solids "wash-out"; however, the ammonia removal capacity provided by the attached growth on the media was able to keep the plant within the ammonia limit even with a concurrent wastewater temperature as low as 7-9^{o}C. The recovery of the system from the peak conditions appeared to be instantaneous, which may be attributed to the attached biomass inventory on the media. In addition, the installation of the structured sheet media in the aeration basins also improved the process stability due to the increased biomass inventory. For example, an effluent ammonia concentration of less than 5.0 mg/L (or non-detectable in summer) was maintained for the entire year from May 2009 to June 2010 in the IFAS system, as compared to the effluent ammonia concentration of 23 mg/L in the winter for the previous activated sludge process.

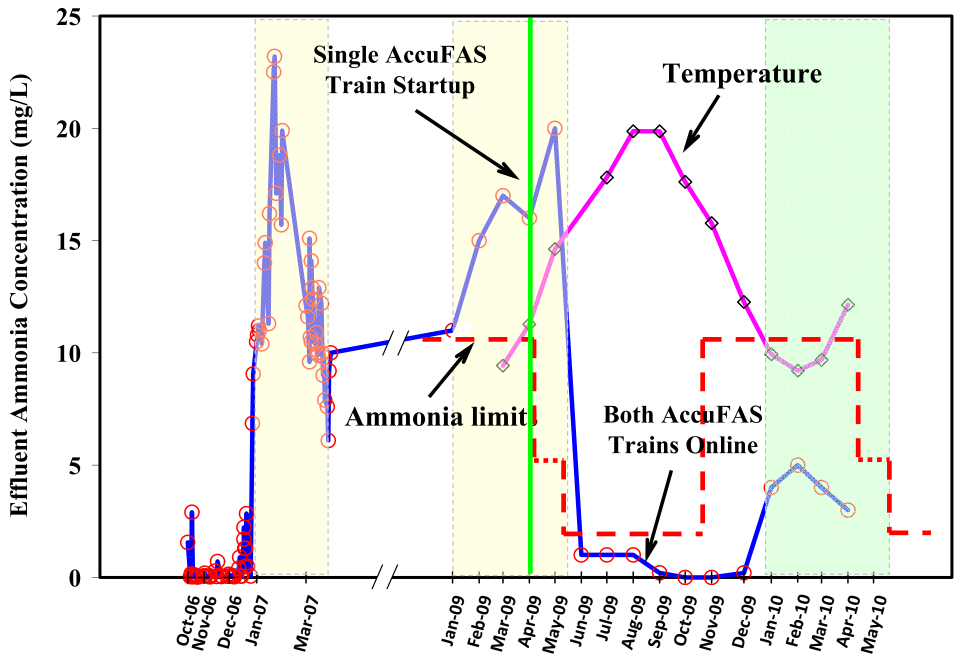


Figure 12 Effluent ammonia concentrations before and after the structured sheet media IFAS upgrade

<u>*BOD and TSS Removal:*</u> Upgrade of the aeration basins with the structured sheet media also improved the plant overall BOD and TSS removal efficiencies (Figure 13). Effluent BOD and TSS concentrations were averaging about 5-7 mg/L during the IFAS period, as opposed to 15-20 mg/L for the activated sludge process. The effluent BOD and TSS concentrations for the IFAS system appeared to correlate well with the influent flow rates, but with enhanced process stability. For example, although the plant flow rate varied from 0.3 to 1.0 MGD, the effluent BOD concentration was constantly maintained below 7.0 mg/L.

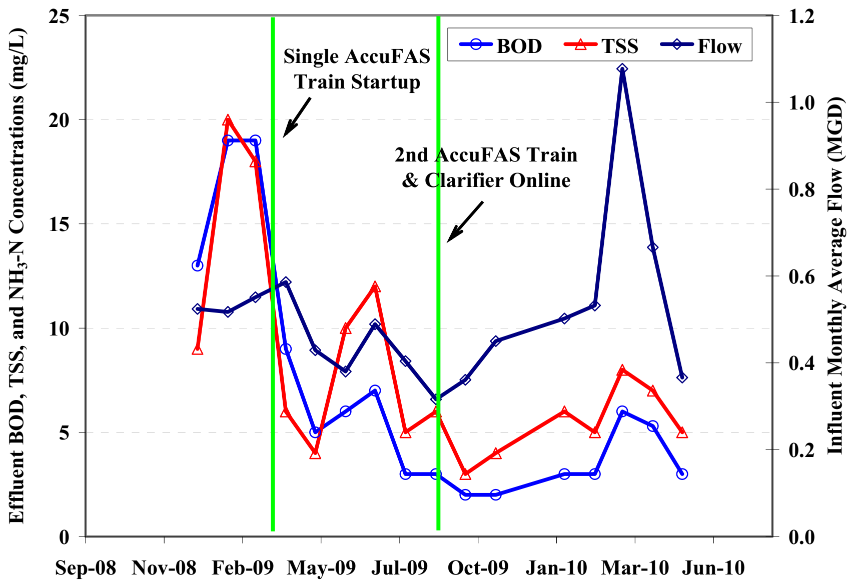


Figure 13 Effluent BOD and TSS concentrations before and after the structured sheet media IFAS upgrade

Solids Settleability: Implementation of the IFAS system appeared to improve the overall settleability of the suspended solids (Figure 14). An average SVI of approximately 100 mL/g was observed in the IFAS system, as compared to 150 mL/g for the prior activated sludge process. It was generally believed that biofilm sloughed off from the media surface tends to have better settleability (Umble et al., 2009). Figure 14 also illustrates that the settleability of the suspended solids deteriorated as the wastewater temperature decreased, primarily due to the reduced differential density between mixed liquor flocs and wastewater at low temperatures. SVI values below 80 mL/g were consistently maintained in the summer period, enabling the IFAS system to be operated at relatively high MLSS concentrations (e.g. ~2,500 mg/L). In contrast, high SVIs over 200 mL/g occurred in the coldest weather, limiting the operating MLSS concentration to be around 1,500 mg/L.

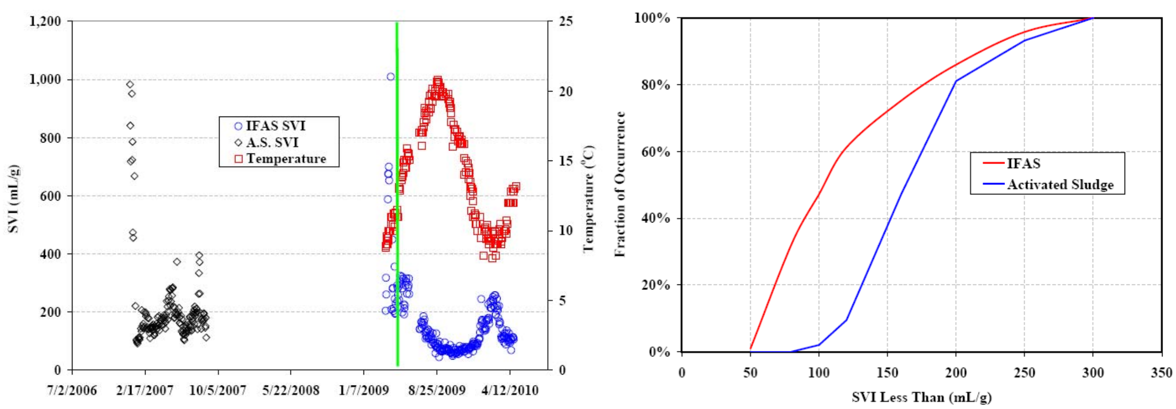


Figure 14 Sludge Volume Index (SVI) of suspended solids before and after the IFAS upgrade in Hopedale, MA WWTP

CONCLUSION

This case study has demonstrated that existing CAS facilities can be retrofitted with structured sheet media to achieve enhanced nitrification without the costly construction of additional tanks. The rigid and stackable structured sheet media blocks allowed for a simple retrofit of the existing aeration basin without the need for baffle walls or media retention sieves associated with other IFAS systems. The implementation of the structured sheet media IFAS system involved integrating media, media support and restraint systems, and aeration diffusers.

Performance data collected for more than a year has shown that the structured sheet media IFAS system was able to consistently meet the ammonia discharge limits even in concurrent extreme peak flow conditions (e.g. three times design flow) and low wastewater temperatures (e.g. 7-9^{o}C). The operation of the structured sheet media IFAS system has proven to be similar to the CAS process and require little attention from the operator. As a unique operational feature of the plug-flow structured sheet IFAS system, tapered aeration can be utilized to minimize filamentous growth, improve solids settleability and clarifier performance, optimize kinetic rates, and provide energy-savings.

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