EIGHT YEARS OF SUCCESSFUL COLD WEATHER NITRIFICATION WITH INTEGRATED FIXED-FILM/ACTIVATED SLUDGE

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ABSTRACT

In 1997 the North Buffalo Water Reclamation Facility in the City of Greensboro could not consistently meet their winter permit limit for ammonia-nitrogen. They decided to try a full scale demonstration of Integrated Fixed-Film/Activated Sludge (IFAS) using a new fabric media called BioWeb. IFAS technology adds a high surface area synthetic media directly into the aeration basins of a conventional activated sludge plant. The additional media yields an attached growth bacterial population that increases the total biomass in the system without overloading the clarifiers. This can be extremely useful and cost-effective for increasing capacity or for increasing treatment levels at existing plants. North Buffalo added the media to one of their four parallel aeration flow trains and have complied with their ammonia-nitrogen permit ever since.

KEYWORDS

Integrated Fixed-Film Activated Sludge, IFAS, Nitrification, Fixed-film

INTRODUCTION

In 1997 the Water Reclamation Manager for the City of Greensboro, Arthur White, needed to correct the winter nitrification problems experienced by the North Buffalo Creek Water Reclamation Facility. For some time the plant had trouble maintaining compliance with their effluent ammonia permit during the coldest months of the year. The plant, which was originally built in 1938, serves the northern half of Greensboro. According to the city's annual sewer report, Greensboro has the difficulty of being located near the top of the Jordan Lake watershed. (Williams, 2004) Their permit is written to protect their receiving stream, the North Buffalo Creek, at its point of lowest flow. At that point 97% of the stream is treated effluent from the wastewater plant. So the permit has significantly lower limits on contaminants such as BOD and ammonia-nitrogen than many other similar cities in the country. Their average monthly winter limit for CBOD is 16.0 mg/l and their summer limit is 8.0 mg/l. For ammonia-nitrogen their

winter average monthly effluent limit is 8.0 mg/l NH3-N and for summer it is 4.0 mg/l. The plant was upgraded from a total capacity of 8 mgd to 18 mgd in 1959 and then voluntarily downgraded to 16 mgd in 1980 in order to treat the wastewater to low limits of ammonia-nitrogen.

The North Buffalo Creek Water Reclamation Facility uses step-screens in their headworks, has primary clarification and large shallow rock media trickling filters, followed by long plug-flow conventional aeration basins and final settling tanks. The flow is divided equally into four parallel aeration trains, each train consisting of two long passes with full floor cover porous stone fine bubble diffused air. The total aeration volume is 4.36 MG. The aeration basins are covered to contain any odors that might be produced. After the aeration basins the mixed liquor from the four trains is combined and then sent to the final settling tanks before being disinfected and discharged to North Buffalo Creek.

Figure 1: North Buffalo Creek WRF overview, including aeration basins with covers

The Water Reclamation Manager, Arthur White, was introduced to Integrated Fixed-film/Activated Sludge (IFAS) technology in 1997. IFAS technology is simply adding a high

surface area media directly into the aeration basins of an existing activated sludge plant to increase the amount of biomass available in the system. IFAS makes it possible to expand capacity at various kinds of activated sludge treatment plants without having to construct new aeration basins or clarifiers. It also can be used to increase treatment levels at existing plants in order to meet new permits for ammonia or total nitrogen.

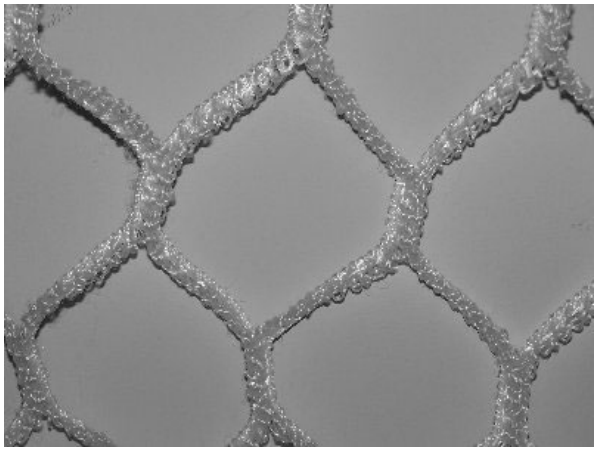
In most conventional activated sludge plants, the treatment capacity is limited by the solids loading on the secondary clarifiers. All the bugs have to be continuously settled and returned to the aeration basin and there is a limit to the suspended growth population that can be effectively maintained. By adding a synthetic media directly into the aeration tank, a new population of attached growth biology is formed and adds to the existing suspended growth bugs. The new population is in the form of a thin layer of film attached to the surfaces of the media. The fixed film biomass is integrated with the activated sludge biomass. Hence the name, Integrated Fixed Film/Activated Sludge technology, or IFAS as it has become known in the industry. It is a hybrid system with fixed biomass and suspended biomass working together to treat even more wastewater or remove higher levels of contaminants.

White was introduced to a new product called BioWeb that was a knit web-like fabric with high surface area designed to be installed directly into aeration basins to create a colony of attached growth biomass in the system. BioWeb was invented and patented by Apex Mills, a textile company in Long Island, NY, in cooperation with the New York City Department of Environmental Protection. The NYC DEP approached Apex about designing a better, stronger material than the Japanese product Ringlace that was being marketed for IFAS at the time. NYC installed BioWeb in their 80 mgd Tallman Island WWTP for a long-term IFAS study.

METHODOLOGY

The City of Greensboro decided to try adding the BioWeb to one of its four parallel aeration trains, as a full-scale demonstration. A technical evaluation estimated that about 60,000 square feet of BioWeb would add enough biomass to have an impact on the ammonia removal in that train. The BioWeb media was made of polyester in the form of a net with three inch diameter hexagonal openings, as shown in Figure 2.

Figure 2: Close-up view of BioWeb loops



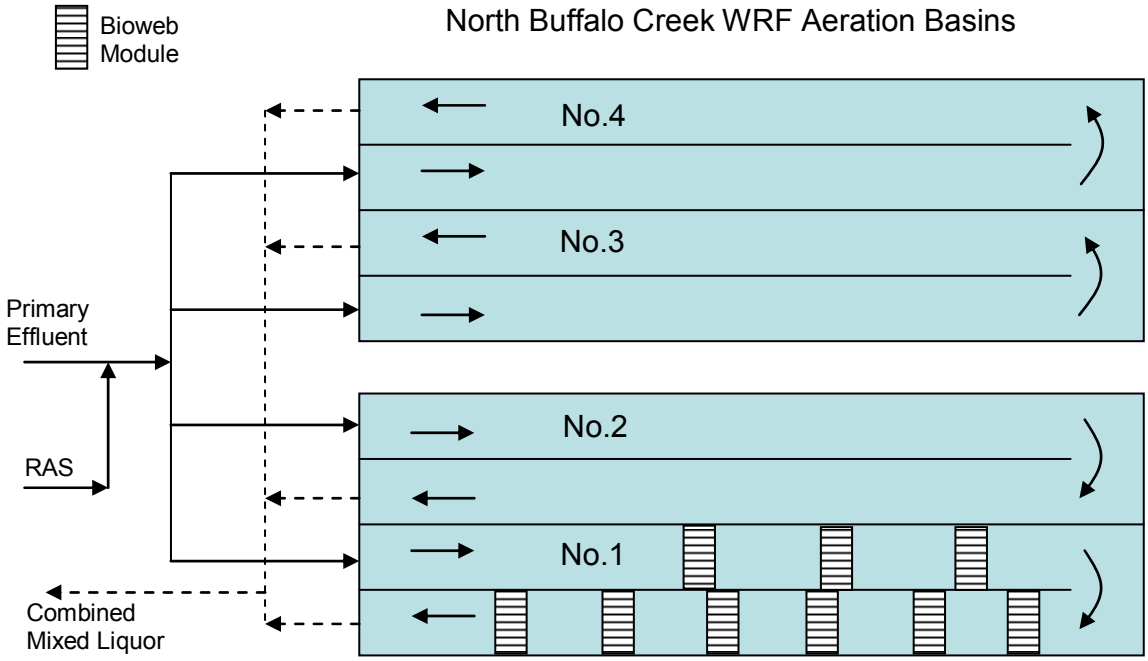
The fabric had hundreds of tiny loops protruding from one side of the material to give it tremendous surface area. The fabric was wrapped in continuous sheets that were then hung vertically on steel frames that were each 10 feet wide, 14 feet long, and 10 feet high. See Figure 3 below.

Figure 3: BioWeb frame with attached biomass after several months of operation

The BioWeb Modules, comprised of the steel frames and polyester fabric were hung from the top of the walls of the aeration tanks, with clearance for the diffusers below. Nine modules were installed in aeration basin No. 1, with three in the first pass and six in the second pass. An area

at the influent end of the first pass was kept free of media for future use as a potential anoxic denitrification zone. Figure 4 below shows a flow schematic of the four aeration basins, each with two passes, and how the BioWeb modules are laid out in aeration basin No. 1.

Figure 4: Flow schematic of the North Buffalo Creek aeration basins



Note that the effluent mixed liquor from the aeration basins is mixed before proceeding to the final settling tanks. As a result, the suspended biology is mixed between the four trains and the IFAS train cannot be completely isolated to see differentiate the effects the added fixed-film has on the suspended population in that train.

All nine of the frames modules were installed by the North Buffalo Creek plant operations personnel in December of 1997. They reported that it was a very simple procedure, requiring the use of a crane, and that all of the modules were installed in one day. The aeration basins were not dewatered during installation so the plant operations would not be interrupted. No change in the surface bubble pattern created by the diffused air was noticed.

The plant manager, Barbara Hicks, reports that she expected to see an increase in oxygen required for the IFAS basin because of the extra bug population, but she saw no such increase. In fact, Water Reclamation Manager, Arthur White, has reported that the air rate supplied to the IFAS basin was decreased by approximately 10% over the other three basins to maintain the set point dissolved oxygen level of 2.0 mg/l. This may be indicative of a 10% increase in oxygen transfer efficiency over the activated sludge, possibly due to bubble retention on the BioWeb media.

RESULTS

In order to compare the effectiveness of the added BioWeb media, mixed liquor samples were drawn from the effluent end of each of the four trains, filtered, and measured for ammonia-nitrogen. The testing took place during January through April, 1998. The overall results demonstrate that on average, the IFAS train removed approximately 20% more ammonia than the other three conventional activated sludge trains. A graph of the results is shown in Figure 5 below, with the dark curve representing the average effluent ammonia of the suspended-growth-only flow trains and the dotted curve representing the ammonia coming from the IFAS flow train. Another way of looking at the results is shown in Figure 6.

Figure 5: Comparison of effluent ammonia-nitrogen in mg/L between IFAS and control trains

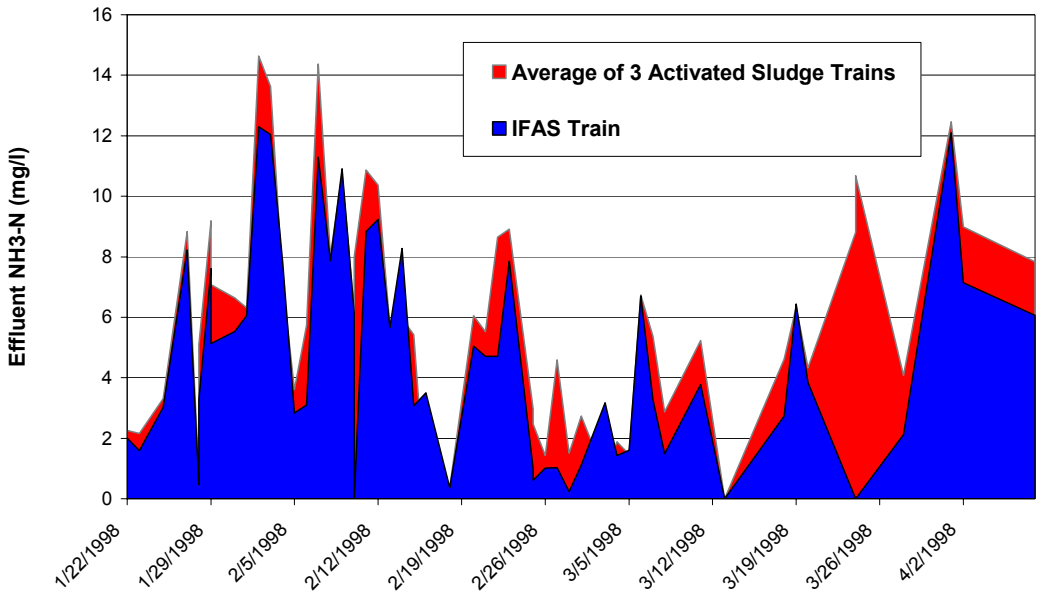
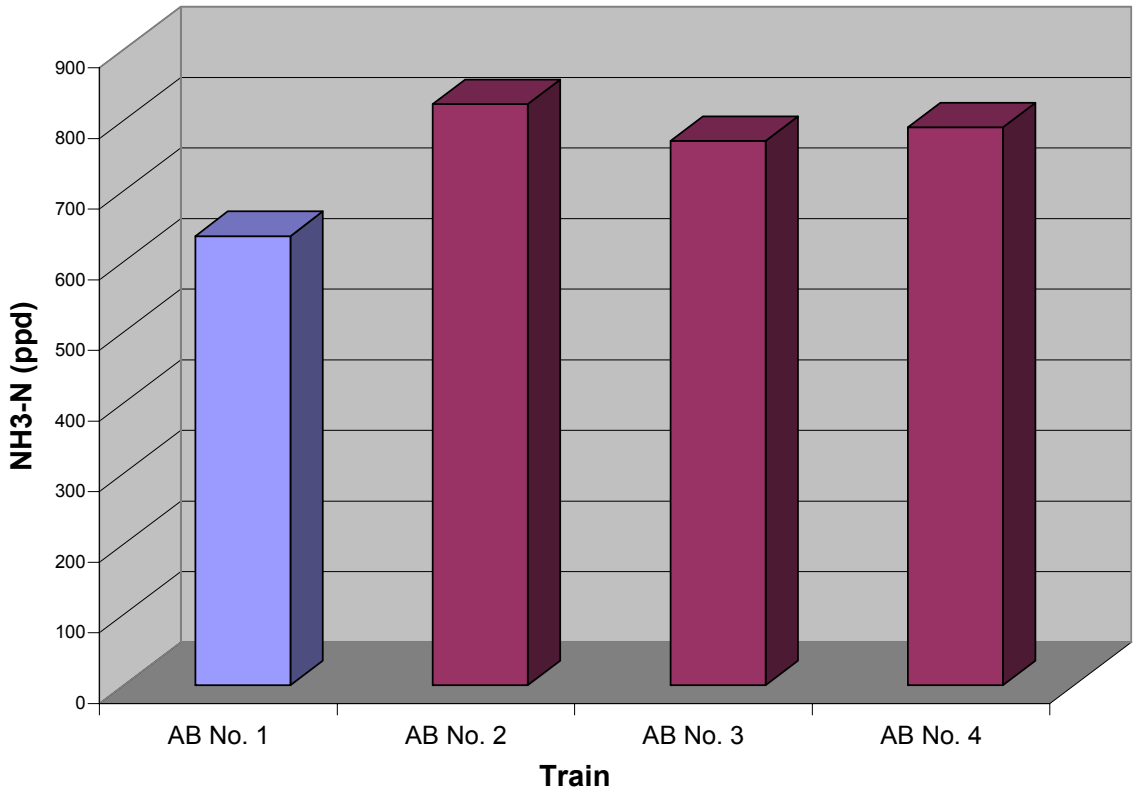
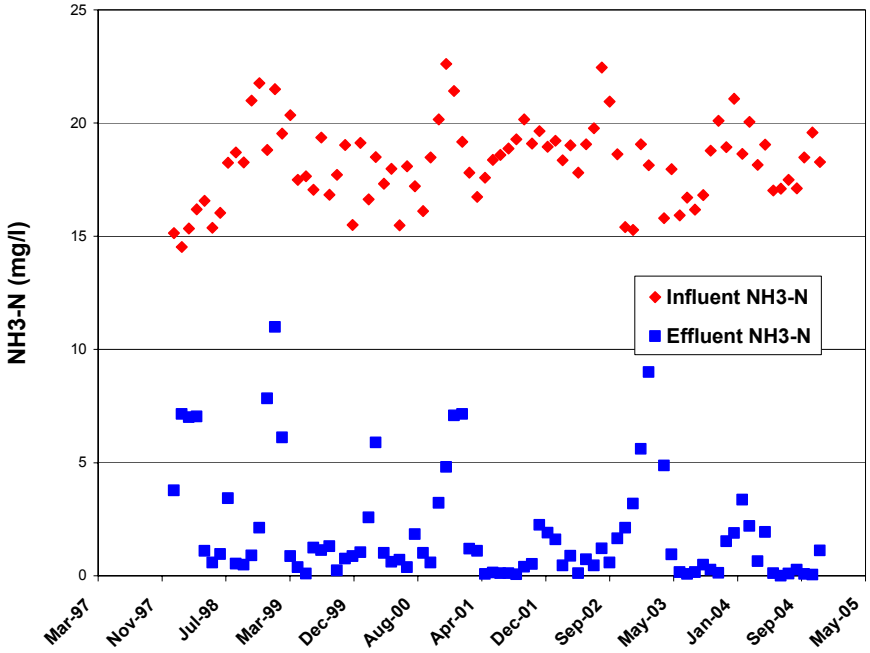


Figure 6: Comparison of effluent ammonia-nitrogen in pounds per day of IFAS verses control trains



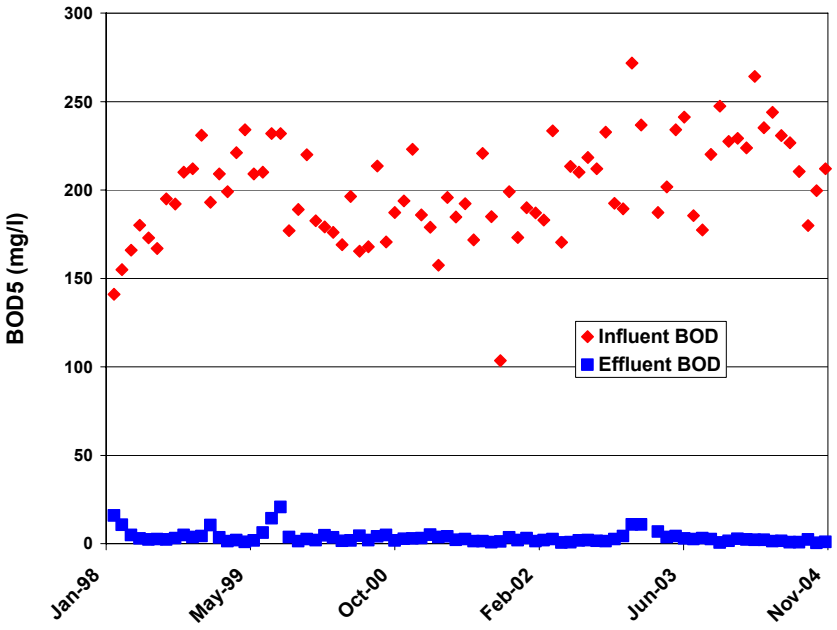
According to Arthur White, since the installation of the BioWeb in 1997, the plant has not had any problems with winter nitrification compliance. Figure 7 below shows the historical ammonia-nitrogen data since the BioWeb installation through the end of last year.

Figure 7: Influent and effluent ammonia-nitrogen data from 1998 through 2004



The North Buffalo Creek plant has also maintained compliance in terms of their effluent BOD permit since that time. Figure 8 shows the BOD data for the same time period.

Figure 7: Influent and effluent CBOD5 data from 1998 through 2004



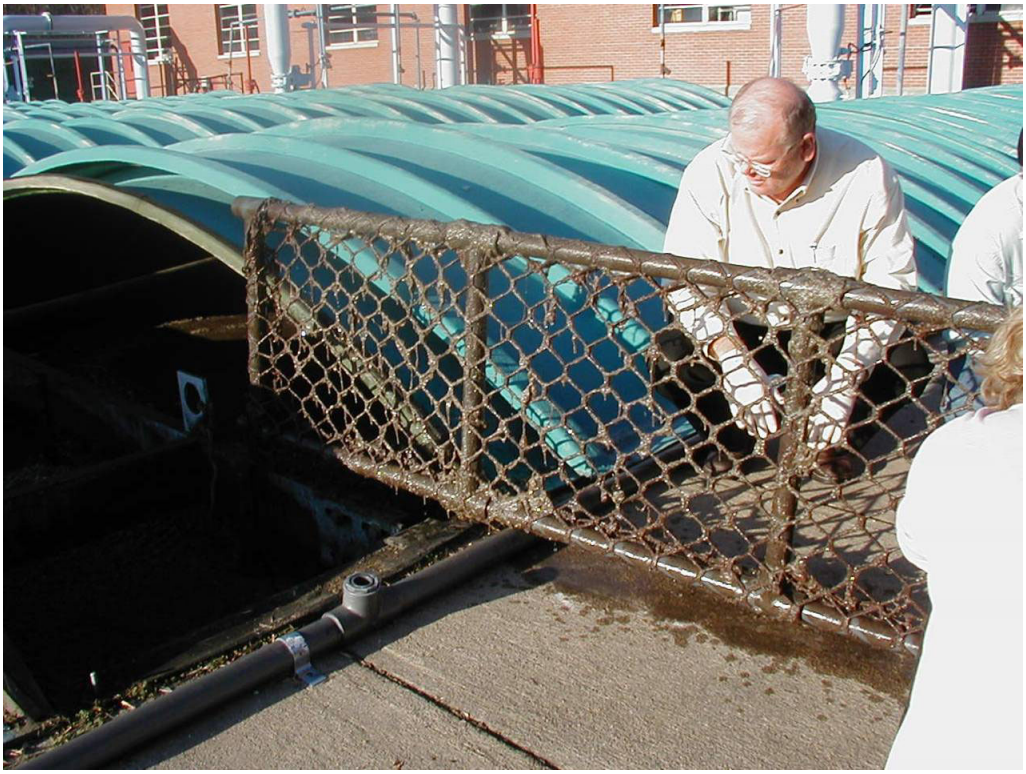
DISCUSSION

In addition to the excellent results of the side-by-side comparison of ammonia-nitrogen between the IFAS train and the conventional activated sludge trains, the plant staff has noticed another interesting benefit to the BioWeb media. After installation of the BioWeb the recovery time for the whole plant from nitrification upsets caused by storm surges peaking as high as 50 mgd was greatly reduced. Plant Manager Barbara Hicks believed that because of the mixed sludges between the four trains, the BioWeb was acting like a seeding device for the suspended growth in all four trains. In effect, the autotrophic bacteria that were attached to the BioWeb would continuously slough off a little at a time from the media and be mixed with the other three aeration basins. This helps the suspended growth nitrifier population reestablish itself much more quickly after a washout.

A few years after the installation of the IFAS media, a fifth aeration train was added to the North Buffalo WRF by converting an existing equalization tank into a complete mix activated sludge aeration basin and converting an old digester tank into a clarifier. The fifth train is completely isolated from the other four process trains and receives about the same amount of flow as each of the other trains. In May of 2006 mixed liquor samples were taken from this fifth aeration train and the IFAS aeration train to be analyzed for an ongoing study of sludge setting properties at Duke University. Both trains had excellent settling characteristics, with DSVI values near 50, but the IFAS sample had a density of 1.05 g/mL while the non-IFAS train had a lower density of 1.0311 g/mL. This could be due to attached growth sloughing off of the BioWeb media in the IFAS train and contributing to the mixed liquor. The higher density could also be due to some unintended Enhanced Biological Phosphorous Removal (EPBR) going on in the mixed liquor of the IFAS train, because that sample exhibited lower soluble P and higher P content in the biomass.

Ultimately the North Buffalo wastewater plant has been able to successfully maintain compliance with their effluent ammonia permit, even in the winter, ever since the BioWeb media was installed in 1997. No maintenance has ever been performed on the media and no operational changes were made because of the IFAS system. A sample rack of the original BioWeb was pulled out for observation for the first time in late 2004 and found to have healthy aerobic biomass with no clogging ragging or predators on the media. The polyester fabric media remains in excellent condition, indicating many more years of life. Figures 8 shows the sample rack being pulled out.

Figure 8: Sample rack of BioWeb media removed for observation in 2004 (Photo courtesy of Freese and Nichols)



CONCLUSIONS

The BioWeb media added to one of four parallel aeration basins in Greensboro's North Buffalo Creek WRF served to demonstrate the benefits of Integrated Fixed-film/Activated Sludge technology. The media was installed in late 1997 in order to see if IFAS could help the plant remove additional ammonia-nitrogen from the wastewater. The demonstration IFAS train has helped the plant resolve its struggle to maintain permit compliance in the dead of winter. The hybrid train removed 20% more ammonia than the other three trains, and the biomass sloughing off of the media acted as a nitrification seed for the rest of the plant after occasional washouts.

ACKNOWLEDGMENTS

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