DEMONSTRATION AND FULL SCALE RESULTS OF A PLANT UPGRADE FOR BNR USING INTEGRATED FIXED-FILM ACTIVATED SLUDGE (IFAS) TECHNOLOGY

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ABSTRACT

In September of 2001 the Windsor Locks WPCA near Hartford, CT underwent a facility upgrade from single stage nitrification activated sludge to an MLE process for biological nutrient removal. The upgrade employed the use of a high surface area fixed media to provide additional fixed biomass to the system for complete nitrification. The Integrated Fixed-Film/Activated Sludge (IFAS) process helped the plant compensate for a shorter aerobic retention time after a portion of the existing basin volume was made anoxic. A demonstration test of the IFAS system verses a control train proved that the attached growth biomass contributed towards the removal of ammonia from the wastewater. The full scale IFAS system helped the plant significantly reduce their total nitrogen discharge to the river without building additional aeration basin volume or clarifiers.

KEYWORDS

Integrated Fixed-Film Activated Sludge, IFAS, BNR, AccuWeb, nitrification, media, Windsor Locks, nutrient trading.

INTRODUCTION

Since most older conventional activated sludge plants were originally designed for simple secondary treatment, major process modifications are usually required to modify a plant for biological nutrient removal. Often this means making a portion of the aeration basin anaerobic and/or anoxic, which reduces the aerobic volume and limits nitrification capacity. Clarifier solids loading is usually the factor that limits the concentration of biomass available for nitrification, so common practice is to increase bioreactor volume in order to increase treatment capacity. This can be a very expensive and sometimes even impossible endeavor, especially where plants are space constrained. One cost effective solution for this situation is adding a fixed-film media to the existing aeration basins, in order to increase the bacterial population without affecting the clarifier loading. This hybrid process is referred to as Integrated Fixed-film Activated Sludge (IFAS) technology.

IFAS Technology

IFAS systems add the benefits of attached growth biological systems to the suspended growth activated sludge process. Some advantages of the activated sludge process are the advanced level of treatment it can provide and the high degree of process flexibility available with most systems. Attached growth biological processes such as trickling filters or rotating biological contactors are inherently stable and resistant to organic and hydraulic shock loadings. Placing high surface area media into activated sludge basins to create a combination of suspended and attached growth biology optimizes the benefits of both of these systems.

Placing high surface area media directly into a suspended growth reactor creates additional active biology above and beyond the limits of the suspended activated sludge system. This can allow for either higher reactor capacity in terms of organic loading or more advanced treatment of the wastewater due to longer sludge age. The additional fixed film biomass does not need to be settled out and returned and therefore does not increase the solids loading to the secondary clarifier, a factor that often limits the treatment capacity of activated sludge systems. IFAS technology addresses the need for increasing activated sludge plant capacity without additional clarifier or aeration basin volume. The fixed biomass also contributes to the ability of the process to respond to organic or hydraulic shock loads and to recover from upsets.

Windsor Locks WPCA's BNR Upgrade

One plant that used IFAS as part of their plant's conversion from secondary treatment to biological nutrient removal is the Windsor Locks Water Pollution Control Authority located near Hartford, CT. This plant discharges to the Connecticut River, a tributary of the Long Island Sound, where environmental officials have specifically targeted a need for nutrient reduction. In 2001, facing new total nitrogen permit limits, the plant went through a major process renovation to convert the plant from a conventional activated sludge system designed for nitrification only to a biological nutrient removal (BNR) system designed to achieve high levels of denitrification.

The targeted effluent nitrogen concentration was calculated from a goal set in terms of pounds of total nitrogen discharged annually. The goal was set by the Town of Windsor Locks through their participation in the Connecticut nutrient trading program in which the state sells credits to POTW's for pounds of nitrogen discharged. Windsor Locks planned to lower their goal for pounds of total nitrogen discharged every year after the BNR upgrade.

The design details for the Windsor Locks activated sludge system are shown in Table 1:

Table 1: Wastewater Design Characteristics

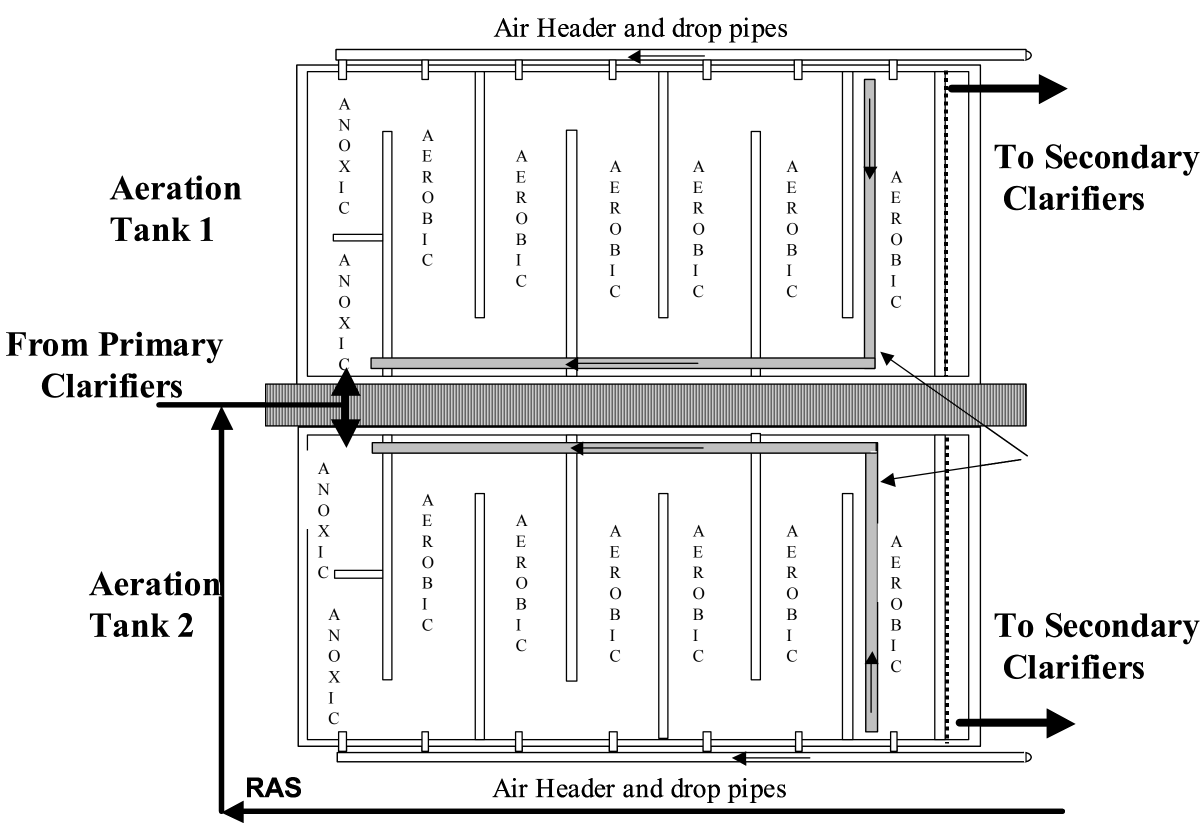
Wastewater Parameter	Value
Influent Flow	1.43 mgd
Influent BOD	187 mg/l
Influent TSS	200 mg/l
Influent TKN	35 mg/l

Aeration Basin HRT	2.62 hours
Minimum Temp	12°C
Effluent TN Goal	<8 mg/l

The existing plant layout included headworks with a bar screen, two parallel rectangular primary clarifiers, two parallel complete mix aeration basins, two circular secondary clarifiers, and a chlorine contact basin. The plant also handles their own biosolids with digesters, thickeners, and belt filter presses.

Windsor Locks contracted the consulting engineering firm Tighe & Bond to design their activated sludge upgrade for nitrogen removal. The engineers chose to employ the Modified Ludzick-Ettinger process for BNR in which nitrified mixed liquor is returned from the end of an aeration basin to an anoxic zone in the front of the aeration basin for denitrification. Additionally they chose to segment the existing aeration basin with baffles to change it from a complete mix configuration to a more plug-flow serpentine arrangement. The new MLE arrangement for the two parallel aeration basins are shown in Figure 1.

Figure 1: Upgraded Windsor Locks Aeration Tank Configuration For BNR



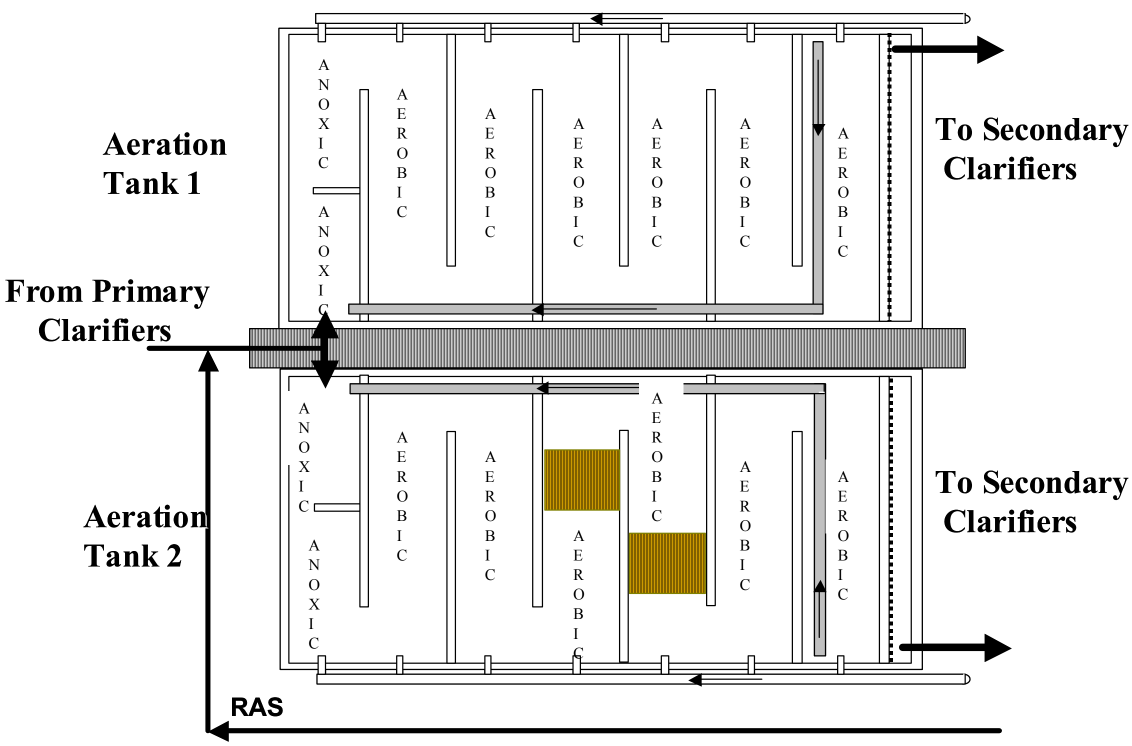
Because of the volume required in each basin for anoxic zones to achieve the degradation of nitrate, aerobic volume was effectively removed from the aeration basins. This volume reduced the aerobic hydraulic retention time and reduced the processes ability to fully nitrify under cold temperatures or unusually high loads. Adding a new aeration basin or clarifier was not a feasible option for increasing nitrification because of the lack of space available at this 1.4 mgd facility. To address this new problem the engineers chose to add a high surface area fixed media to the aerobic portion of the activated sludge basins, creating a hybrid IFAS process. The fixed media would contribute additional aerobic biomass to the system, increasing the SRT to allow complete nitrification and stabilizing the entire process.

METHODOLOGY

The engineers created a performance-based specification to allow different IFAS media suppliers to bid on the project. The specification called for the IFAS system to remove 83 lbs per day of ammonia above and beyond what the purely suspended growth system would remove. The IFAS system suppliers could specify the appropriate amount and configuration of media according to their own designs. After the competitive bid of different IFAS systems the media chosen was the AccuWeb, which is a knit polyester fabric media in a hexagonal mesh with small filaments in the form of loops protruding from one face of the fabric. The loops give the media very high surface area. The approximate diameter of the hexagonal openings in the mesh is one inch. The fabric media was manufactured in continuous sheets, in this case six feet wide, and was wrapped vertically on stainless steel frames so that the sheets were spaced approximately three inches apart. The full-scale design of the IFAS system called for four AccuWeb modules to be installed in each of the two aeration tanks. Each frame was 6 ft. wide, 8 ft. in length, and 12 ft. in media depth with 3 ft. legs. Each module would hold 4,176 ft^2 of fabric media. The frames were designed to sit on rails mounted on the walls of the tank so that the bottom of the media sheets hung approximately two feet above the fine bubble disc diffusers. The aeration from the full floor cover diffusers was expected to provide adequate mixing of oxygen and liquid throughout the entire media module.

In order to verify the design of the IFAS system, the engineer specified that a demonstration be conducted for six weeks at the minimum wastewater temperature for the plant. This was achieved by installing part of the IFAS media into only one of the two parallel process trains and comparing the ammonia removal of the two trains for six weeks in February and March of 2002. Two AccuWeb media frames were installed in Aeration Tank 2, as shown in Figure 2.

Figure 2: IFAS Demonstration Layout



During the demonstration period samples were collected once a week, four times a day every two hours to create an eight-hour composite sample. Because the effluent from the two aeration basins was mixed before going to the clarifiers, samples had to be taken from the mixed liquor, downstream of the IFAS media modules. Samples were also taken from the mixed liquor upstream of the media modules, and from the combined primary effluent channel. These samples were filtered to remove any suspended solids and their ammonia concentration was measured in the plant laboratory using a Hach Test-N-Tube ammonia kit. Separate sets of composite samples were also sent to an independent lab for complete analysis.

The amount of media included in the demonstration study was purposely designed to be just enough for a partial contribution to the ammonia removal and not enough to provide complete nitrification for that system. The dissolved oxygen in both aeration basins was automatically controlled to stay at 2.0 mg/l. The goal of the study was to find a difference of 2 mg/l ammonia between the two process trains in the mixed liquor downstream of the media. This small difference was based on the assumption that each of the two aeration tanks received exactly equal influent flows. In the beginning of the demonstration period some test results were not as expected so eventually the influent gates and effluent weirs were carefully examined to find out if the flows were equal. It was discovered that the effluent weirs were not set the same and the

IFAS aeration tank was treating more flow than the control train. This was immediately corrected. Also on some occasions during the test period certain samples were found to have no ammonia at all, which made a quantifiable comparison between the two trains impossible.

RESULTS

The results of this study showed that the IFAS train removed significantly more ammonia than the control train. Figure 3 shows the results in terms of the difference in ammonia concentration between the two trains. Figure 4 shows the results in terms of pounds of ammonia removed.

Figure 3: Mixed Liquor Ammonia Concentration Downstream of AccuWeb

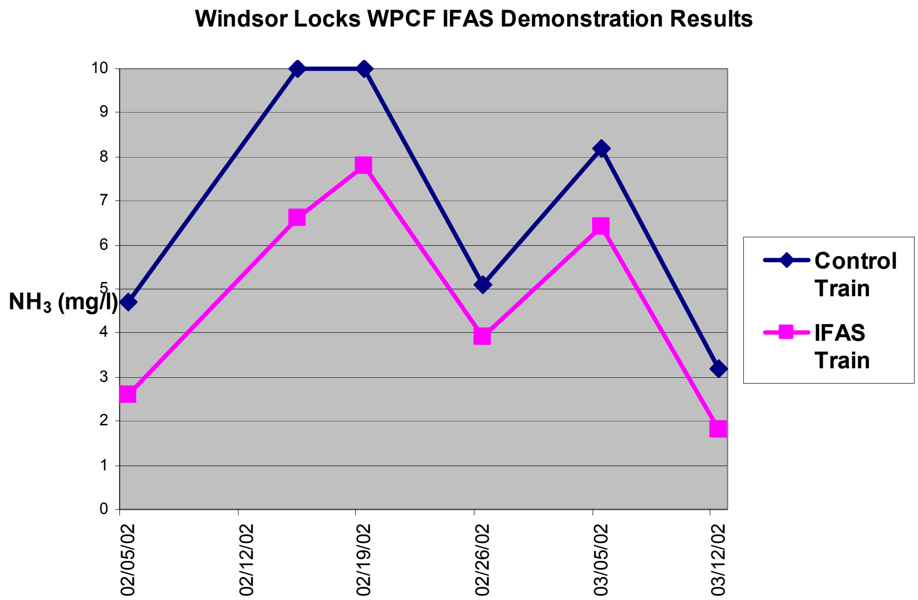
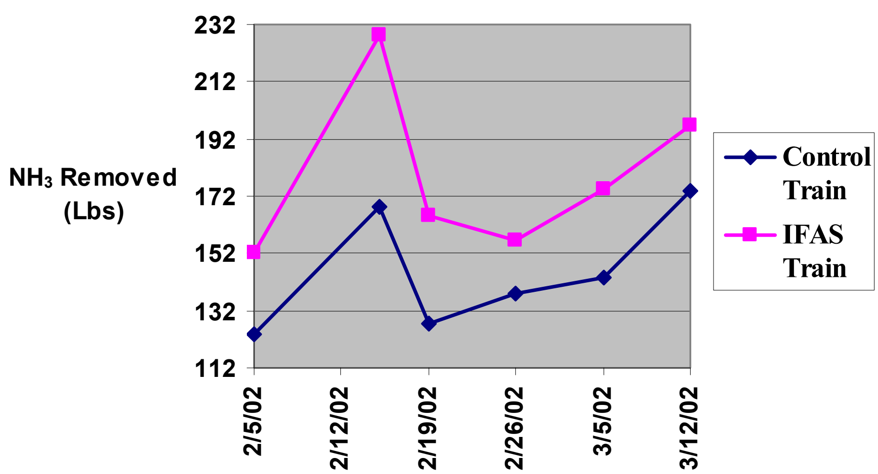


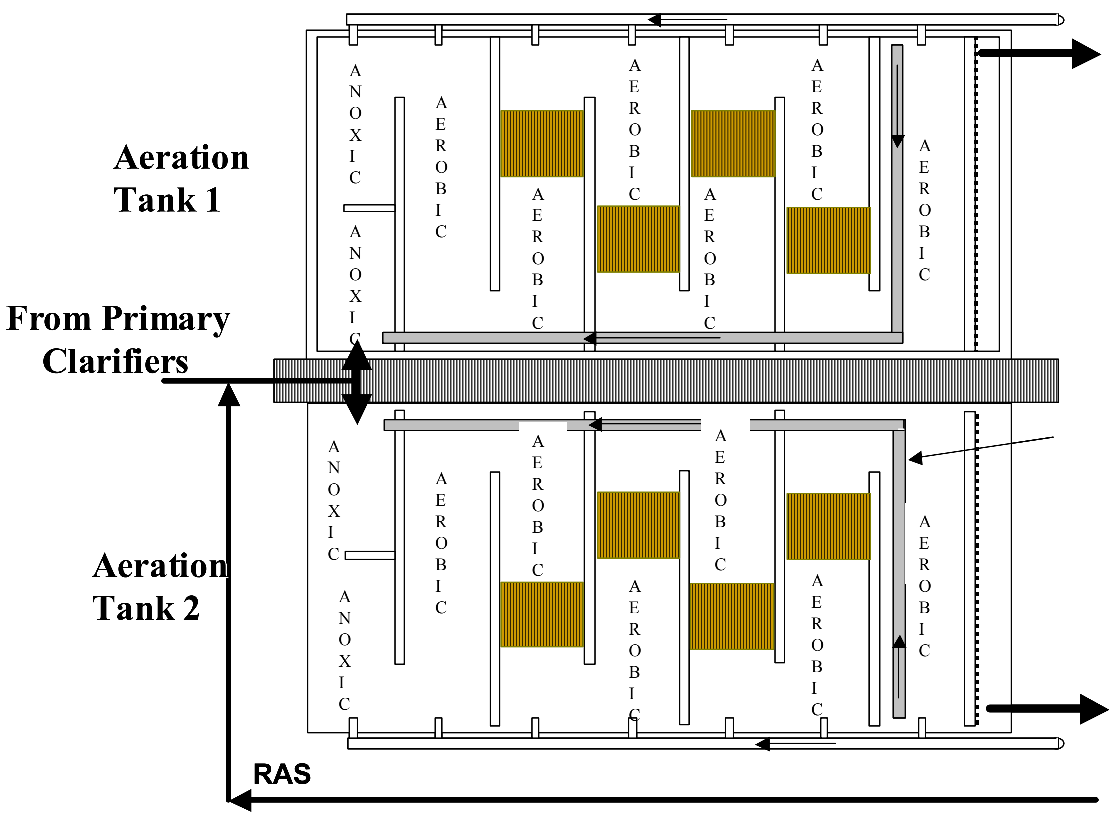
Figure 4: IFAS Verses Control Pounds Ammonia Removed



DISCUSSION

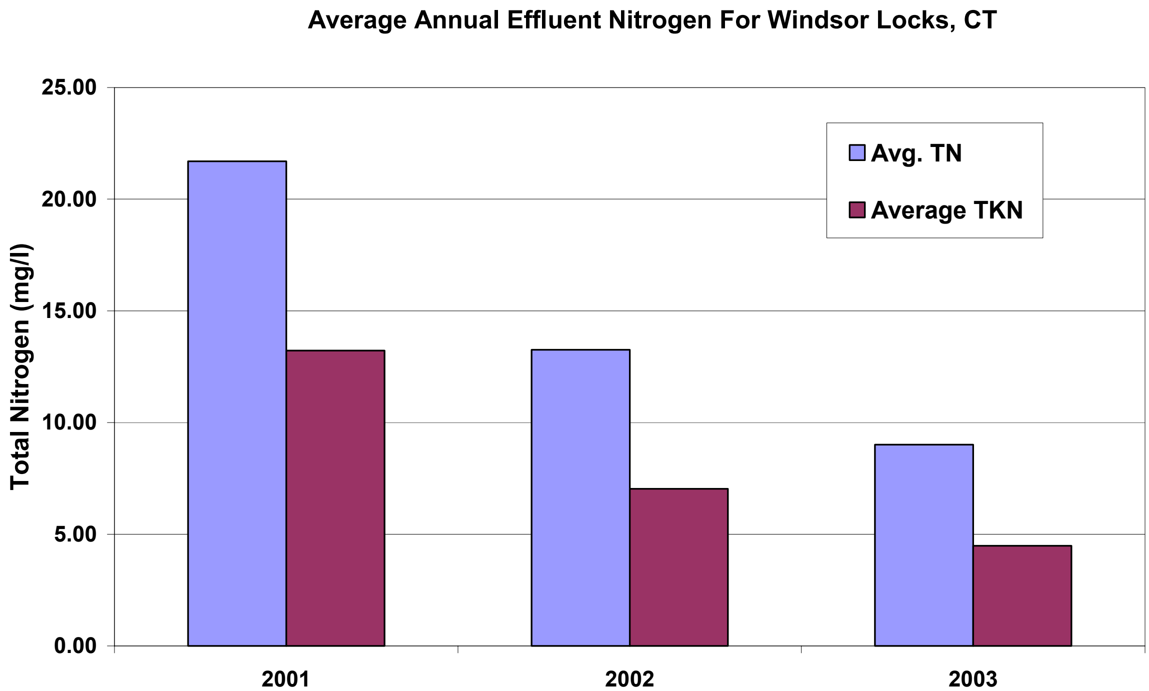
Because of the outstanding results of the demonstration, six more modules were installed in the aeration basins, for a total of four per train. Figure 5 shows the layout of the plant with the IFAS media modules.

Figure 5: Full Scale Layout of IFAS Media Modules



Full scale performance of the plant in the BNR mode with the IFAS media has been excellent to date, especially compared to historical performance before the upgrade. Ammonia removal in the winter months has been better and more consistent. In 2002 and 2003 the plant was able to meet their goals for total pounds of nitrogen discharged to the Connecticut River. Figure 6 shows the trend in improved treatment over the past three years. Note that the first two frames were installed in October of 2001 and the remaining six were installed in August of 2002.

Figure 6: Full Plant Annual Results for Windsor Locks



Additional benefits the plant has seen from the IFAS upgrade include better SVI test results and improved recovery from shock loads and plant upsets. This is attributed to the fixed-film component of the system, which traditionally has better sludge characteristics and is more able to handle toxic shock loads.

CONCLUSIONS

The side-by-side comparison of an IFAS system using AccuWeb media and a control activated sludge train demonstrated that the IFAS system had considerably more capacity for ammonia removal than the control. Over the course of two months in the winter of 2002 the IFAS process train removed an average of 33 lbs more ammonia-nitrogen than the parallel control activated sludge train. That translates to a 32% improvement in nitrification capacity with the AccuWeb media.

Based on the demonstration results, the full scale installation of the IFAS media removes approximately 132 lbs more ammonia than the conventional activated sludge system alone would. Full plant conversion to the MLE process for nitrogen removal, along with the full IFAS installation, has resulted in a 65% decrease in average effluent TKN and a 60% decrease in average TN from 2001 to 2003.