Nitrifying in the Cold

A Wisconsin facility experiments with IFAS to ensure nitrification in winter

Douglas J. Nelson and Thomas R. Renner

In 2004, the State of Wisconsin Department of Natural Resources decided that the 1.5-mgd (5700-m^3/d) Village of Mukwonago Wastewater Treatment Facility (WTF) must remove ammonia year-round. If the WTF continued to rely on its conventional activated sludge facility, maintaining nitrification during winter in southeastern Wisconsin would require several additional aeration tanks to provide the higher solids retention time (SRT) to ensure nitrification.

But instead of beginning construction planning immediately, the community wanted to test other options that could avert the construction and get the needed performance out of the existing tanks.

The facility began an evaluation of integrated fixed-film activated sludge (IFAS) technology using a full-scale demonstration test program. WTF ran two sets of experiments using parallel IFAS and non-IFAS process trains from January through March 2006 and January through March 2007 to evaluate the ability of IFAS technology to meet the facility's new ammonia removal requirements without constructing additional aeration tanks.

IFAS

The facility chose an IFAS system that consisted of a number of metal racks that supported open-weave media, which provide a surface for biomass to attach and remain in the aeration basin.

In an IFAS system, the attached biomass effectively increases the mass of solids available to treat wastewater without a proportional increase in the mixed liquor suspended solids (MLSS) concentration. In Mukwonago's case, theoretically,

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The Village of Mukwonago (Wis.) Wastewater Treatment Facility turned to fixed-film activated sludge treatment instead of building additional aeration tanks for nitrogen removal.

the lesser amount of suspended biomass made feasible by use of IFAS reduced the solids loading rate to the secondary clarifiers, thus ensuring that the clarifiers would be able to handle future flows and loadings. Testing protocols and WTF operations were developed to determine if IFAS could meet the required nitrification performance at this facility and also to measure the limits of the technology compared to a conventional suspended-growth activated sludge facility. The facility has two separate and parallel process trains that were operated with equivalent influent for comparison purposes.

Mukwonago WTF in a Nutshell

WTF consists of a headworks, including comminution, influent pumping, and aerated grit removal, followed by two identical independent process trains — denoted as north and south — consisting of primary clarification, aeration using coarse-bubble diffusers, and final clarification. The two parallel aeration basins provide a hydraulic detention time of 6.5 hours at average design flow. Final clarifier effluent is combined, disinfected using chlorination, dechlorinated, and pumped approximately 1 mi (1.6 km) to the Fox River.

Return activated sludge is pumped by dedicated and isolated piping from each of the final clarifiers back to the aeration tanks without commingling. Waste activated sludge is anaerobically digested and dried on sand drying beds prior to disposal on agricultural lands. The secondary digester is decanted nightly, with supernatant returned to the WTF headworks.

The fact that the WTF has two parallel, independent process trains made it an excellent site to perform the full-scale IFAS demonstration test. At the time of the IFAS project, WTF was operating at approximately 50% to 60% of its design flow and loadings.

The First Season

To prepare for the first season of experimentation, in December 2005, the aeration tank in the south process train was equipped with new fine-bubble air diffusers and 10 fixed-grid-type media IFAS modules sized by the manufacturer to provide approximately 5410 lb (2454 kg) of fixed biomass. This is the equivalent of 3200 mg/L volatile suspended solids. In late December 2005, mixed liquor was transferred from the north aeration tank to the south (IFAS) aeration tank, and all primary clarifier effluent was directed to the south aeration tank. During January through March 2006, all WTF flows were processed in the IFAS aeration basin in an attempt to duplicate full WTF design conditions.

Initially, it was hoped that nitrification testing could be accomplished in this first season. However, testing was not successful for several possible reasons:

- Very cold weather in December and resulting cold wastewater temperature prevented the establishment of nitrifying biomass on the IFAS media panels in advance of the test period.
- Higher than anticipated organic loads significantly overloaded the single aeration basin beyond design criteria, leading to lower than expected SRT and loss of the nitrifier population.
- Possible industrial shock loads were received during the test period.

Experience gained during the first season showed facility staff that utilization of both process trains would be necessary to evaluate IFAS in the following winter season. The testing objective for the second season was to run each process train at a progressively lower suspended-growth SRT to evaluate the effects of IFAS in delaying loss of nitrification. This, in turn, would provide quantification of the IFAS biomass in the aeration basin and allow a rational prediction of WTF performance as flows and organic loadings increase in the future up to full WTF design loading parameters.

The Second Season

To prepare the north aeration basin for the side-by-side performance testing, it was converted in fall 2006 from coarse- to fine-bubble diffusers, which greatly simplified balancing of air to the two aeration basins. This also provided for similar conditions in both basins.

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The facility added 10 IFAS modules with fixed-grid-type media. The manufacturer sized the units to provide approximately 5410 lb (2454 kg) of fixed biomass.

To prevent commingling of biosolids between the north and south process trains, facility staff isolated the wastewater flows starting at the primary clarifier effluent troughs. The wastewater flow split between these two clarifiers is dependent on the relative elevation of the primary clarifier effluent weirs.

The MLSS concentration was maintained independently in each aeration tank to approximate the SRT that would be feasible under WTF full design flows and loading conditions. The MLSS in the IFAS tank was maintained at a lower value to compensate for the theoretical quantity of biomass attached to the IFAS modules.

Flowmetering Challenges

Performance-testing the two process trains operated independently presented several challenges. The WTF was never equipped with flowmetering or sampling facilities within the process, and temporary flowmeters and flow composite samplers had to be set up.

Low wastewater flows encountered during the winter testing, compounded by relatively inaccurate primary metering devices (straight weirs), resulted in flow data that was often suspect. Flows totalized by the temporary flowmeter agreed poorly with the WTF primary influent flowmeter.

The primary clarifier effluent flowmetering relied on two temporary rectangular, 2-ft-wide (0.6-m-wide) straight weirs and a dual-channel ultrasonic flowmeter. The flows were recorded on a temporary supervisory control and data acquisition computer.

Temporary flowmetering is difficult at best. Much effort should be made to maximize accuracy within the constraints of field conditions. At this facility, a V-notch weir arrangement would have yielded better results if the low probability of wet-weather-related high flows had been considered.

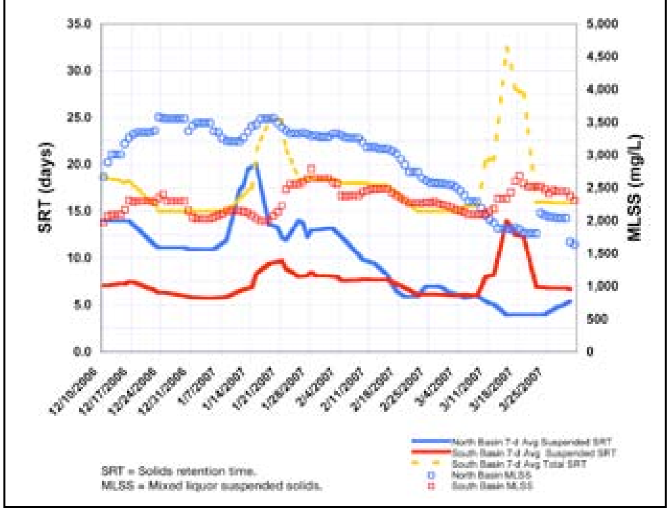
Much of the test data relies heavily on flow rates derived from this temporary flowmeter. For example, the resultant flow rate to each process train was used to pace one influent- and two final-clarifier effluent composite samples, and process parameters, such as mass loading rates and sludge age.

Other Challenges

To sample the aeration basin influent (primary clarifier effluent) and final clarifier effluent, the staff used three temporary 120-V refrigerated samplers. To reduce the volume of lab work, the staff assumed that the characteristics of the primary clarifier effluent were similar from each unit.

To get the samples for analysis, one sampler drew from the effluent trough of one of the primary clarifiers, and two units sampled from the effluent troughs of the two final clarifiers. To protect each sampler from freezing in the bitter cold, premanufactured polyethylene enclosures — approximately 4 ft (1.2 m) wide × 6 ft (1.8 m) high × 3 ft (1 m) deep — were purchased. WTF staff insulated the enclosures with 2-in.-thick (50-mm-thick) polyurethane foam boards and heated the enclosures with portable electric heaters. The sampler hoses were heat-traced and enclosed in a PVC pipe between the sampler enclosures and

Figure 1. Field Data



SRT = Solids retention time.
MLSS = Mixed liquor suspended solids.

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sampling point. Staff routed the signal cables between the flowmeter and samplers over the ground surface and protected them where they crossed walkways by nestling them in natural joints in the concrete.

Despite being insulated and heated, the primary clarifier effluent sampler froze up during the first subzero-weather day, causing a loss of data that day. Additional weatherstripping of the enclosure solved the problem.

Laboratory Burden

In addition to uncertain flows and samples, parallel process testing of two trains presented a significant challenge for the WTF's wastewater testing laboratory. Much of the effort expended to perform this full-scale process testing was provided by the WTF staff. The data obtained by the WTF operators included, in addition to their normal workload, tending three additional samplers and performing more than 980 additional measurements or laboratory analyses during the test period. These tests included suspended solids, volatile suspended solids, biochemical oxygen demand, ammonia, sludge volume index, pH, and more.

To compound the challenge, going into the second season, the WTF was operating short-handed, with only two full-time and one part-time operator. As a result, the extra workload anticipated for lab analyses was out of the question. Fortunately, in late 2006, a new lab-qualified superintendent was hired, and subsequently all routine and test-related lab analyses were performed onsite in the WTF lab. The staff taking on the laboratory duties improved turnaround time for WTF operating data and significantly reduced costs, but the sheer burden of effort required made the prospect of extending testing beyond the original 3-month schedule impossible to consider.

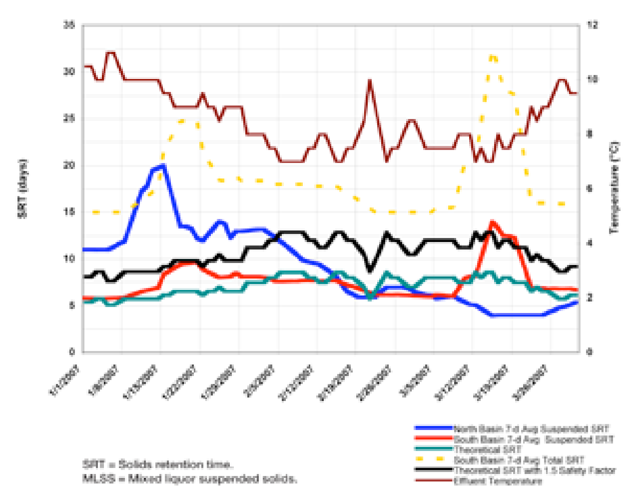
In retrospect, contract lab testing would have reduced the burden of responsibility on the already overworked WTF staff and would have allowed more flexibility to extend the test if it appeared advantageous to do so.

Second Season Findings

Stress testing of the IFAS system was intended to show its performance in very cold mixed liquor, typically 45°F (7°C) or colder at this facility, when the bioactivity of the nitrifiers is at a minimum. The Wisconsin winter of 2006–2007 failed to produce extended periods of bitter cold weather; and, as a result, the mixed liquor temperatures hovered between 46°F (8°C) and 50°F (10°C) most of the time. This made it more difficult to reduce the SRT enough to lose the nitrifier population in either the IFAS or non-IFAS process train.

Actual testing started Jan. 3, 2007. For purposes of this study, *SRT* is defined as the mass of sludge under aeration divided by the mass of biosolids wasted per day. As shown in Figure 1 (p. 56), at the start of testing, the north aeration bay MLSS was 3250 mg/L, yielding a 12-day SRT; the south (IFAS) aeration bay MLSS was 2200 mg/L, yielding a 6-day suspended solids SRT and a 15-day combined SRT with IFAS.

Figure 2. Theoretical Versus Actual SRT



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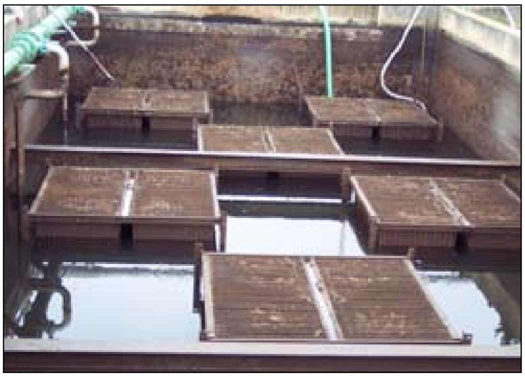

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Biomass attached to the growth media provides more bacteria to treat the wastewater without a corresponding increase in mixed liquor suspended solids concentration.

By March 11, the north basin MLSS was gradually reduced to a low of 2000 mg/L MLSS and a 5-day SRT, while the south basin MLSS remained between 2250 and 2500 mg/L with a 6- to 7.5-day suspended solids SRT and 15- to 18-day combined SRT. It was planned to operate the south basin at a lower SRT, but sludge wasting problems prevented this.

Also, sludge production, sludge wasting, and solids residence time all rely on measurements of sludge volume and WAS solids concentration. WAS suspended solids concentration is sampled by a single grab sample made during the time sludge is wasted each day. Dilution of the WAS during wasting is suspected to have resulted in overestimation of the mass of sludge wasted each day. This, in turn, could have resulted in an underestimation of the SRT.

Figure 2 (p. 57) shows the theoretical required SRT for cold-weather nitrification based on the WTF mixed liquor temperature measured and actual field-measured SRT. During most of February and the first half of March, WTF staff were operating the south (IFAS) aeration basin close to the theoretically required SRT for ammonia removal, while the north basin fell generally below the minimum SRT from March 1 and later.

Ammonia bleed-through was first detected from the north aeration basin on Feb. 25, and the problem worsened until March 15, after which some of the north basin flow was redirected to the south basin. The diversion led to 40% of the flow going to the north aeration basin and 60% to the south aeration basin.

On March 20, flows to the north aeration basin were reduced further so that the north basin was treating only 25% of the flow. These two flow diversions were done as a final stress test of the IFAS system.

The south (IFAS) basin reacted to the diversions by showing ammonia bleed-through starting on March 15. But, despite being saddled with a sustained 50% higher flow and loading from the stress test, the south (IFAS) basin recovered by the end of testing, March 29.

The north basin field-testing verified that ammonia bleed-through — which indicates loss of nitrifier population in cold water — began after sustained operation near an SRT of 7.5 days, the theoretical minimum. Applying a 1.5 safety factor to this minimum sludge age to account for shock loads and industrial discharges indicates that an 11-day SRT should be the minimum design for the facility operating without IFAS.

The results for the south basin (IFAS) were less clear. The inability to reduce the MLSS enough to induce ammonia bleed-through (prior to flow diversion activities) does not allow conclusions as to how much impact the IFAS modules provided. However, the rapid recovery of the IFAS basin to the sustained 50% increase in flows and loadings suggests that the IFAS system will be resilient and capable of recovery from shock loads even in relatively cold (10°C) mixed liquor temperatures.

The Bottom Line

One of the primary objectives in this test was to predict the ability of the WTF to remove ammonia at the full design flows and loadings. The second season of testing was conducted at flows and loadings of approximately 51% of the full WTF design parameters. The north aeration basin achieved the required design SRT of 11 days at an MLSS concentration of 3200 mg/L. At full design conditions, in order to maintain an 11-day SRT in the north aeration basin, the MLSS would have to be more than 6000 mg/L, which is an impossibly high MLSS for the WTF to handle.

At full design loadings, the south (IFAS) basin, with more than 5410 lb (2454 kg) of attached microorganisms, can achieve the same 11-day combined sludge age under full flows and loadings at an MLSS concentration of 2960 mg/L. Furthermore, the IFAS attached growth media provide a stable reservoir of nitrifier population that is resistant to washout during storm flow events.

Regarding the problems encountered conducting demonstration testing, experiences learned in both seasons of testing suggest that more attention be given to the temporary equipment earlier in the project. The limited demonstration testing time available due to cold-weather constraints makes it imperative to have everything up and running well in advance of the actual testing in order to resolve unexpected problems in time.

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