Lean, mean operational excellence machine

Massachusetts facility uses less energy and chemicals, improves maintenance while saving money

Grant Weaver

Thanks to effective team creativity, effluent quality at the City of Westfield, Mass., Water Pollution Control Water Recovery Facility is improving while chemical use and electrical consumption are declining. The facility discharges less than one-third of its permitted concentrations of biochemical oxygen demand (BOD) and total suspended solids (TSS). Phosphorus concentrations consistently meet all permit requirements. And, although not required by permit, the facility removes more than 75% of influent nitrogen.

◀ **During the past few years, the operators at the City of Westfield Water Pollution Control Water Recovery Facility have improved maintenance and phosphorus removal while reducing operating costs. The operators include (front row) Bob Forry, Jim Lewis, Jon Roushia, Ken Gagnon, (second row) Mitch Therrien, Jeff Thayer, Jeff Gamelli, (third row) Don Hawley, Chris Hall, and Bob Pluta.** Courtesy City of Westfield Water Pollution Control Water Recovery Facility

Additionally, stepped-up maintenance has equipment working more reliably, and the facility's structures, buildings, and grounds are being made to look as new. Even with all these improvements, operating expenses have dropped by $300,000 for each of the past 2 years. (See Figure 1, p. 42.)

New people and an expanded facility

Westfield's ongoing effort to provide better treatment, at ever lower costs dates to 2005 when Public Works Director Dave Billips hired Ken Gagnon as foreman. Upon arriving, Gagnon began building a work order system that today proves to be the heartbeat of the facility's operation. With only minimal experience with wastewater treatment (less than one year at the nearby Chicopee, Mass., water resource recovery facility), Gagnon's 21 years with a textile manufacturer and 5 years' experience with Westover Air Force Base's plumbing division proved to be just what Westfield needed.

Getting the maintenance right

Today, Gagnon's work order system has standardized Westfield's operations and maintenance functions. Software for the computerized maintenance management system (CMMS) was purchased in 2004 for $5000 just before Gagnon arrived.

This CMMS replaced an almost nonexistent preventive maintenance program. Today, almost every task – from emptying office trash cans to daily lab duties to annual belt press preventive maintenance – is included in the work order system. The facility completed its 100,000th work order in May 2017.

When not overseeing a maintenance task, Gagnon manages the work order system. In developing the 1621 work order tasks programmed into the system, his first step was to review all facility maintenance manuals. Manufacturer's maintenance recommendations were developed into work orders. With time, work orders became more operator friendly to include a list of tools needed for tasks, photos of the equipment, and even a library of videos.

Work orders are prepared before shifts and placed into each employee's box. The day's tasks are ready and waiting upon operators' arrival. As tasks are completed, Gagnon updates the CMMS for work order completeness, and equipment and supply inventory. He also removes obsolete tasks and creates new ones as equipment and processes change.

As the work order system became routine and staff found the system to be working for them, the facility added operational tasks. Now, little happens at the facility that is not catalogued and tracked by a work order. Thanks in large part to the work order system, the Westfield Water Recovery Facility is operating at high efficiency with few equipment breakdowns. Together with the support of Public Works director Dave Billips and the outstanding efforts of their staff, deputy superintendent Jeff Gamelli and foreman Ken Gagnon have revolutionized the WRRF, benefitting the customers who pay the bills and the environment the WRRF was built to protect.

Optimizing phosphorus removal

Westfield completed an expansion in 2004 and its seasonal phosphorus limit was rewritten as a year-round limit. Before the expansion, as a 15-ML/d (4-mgd) facility, staff members routinely met the 1.0-mg/L April through October phosphorus limit. After expanding to 23 ML/d (6.1 mgd), the WRRF struggled to maintain compliance with year-round limits: 0.46 mg/L total phosphorus (TP) during summer and 1.0 mg/L TP during, often frigid, winter months.

Historically, Westfield staff added sodium aluminate to meet the facility's seasonal 1.0-mg/L limit. Concerns with freezing temperatures prompted staff to switch to polyaluminum chloride (PAC), a chemical that works well in several New England facilities. Quizzically, PAC did not work in Westfield.

Westfield staff members put on their collective thinking cap in 2013 when the facility was failing to meet its phosphorus limits. Despite the addition of hundreds of thousands of dollars of PAC, sodium aluminate, and caustic soda, the recently expanded facility was failing to meet its new phosphorus limit. Conventional treatment was declining, and the frustration was palpable.

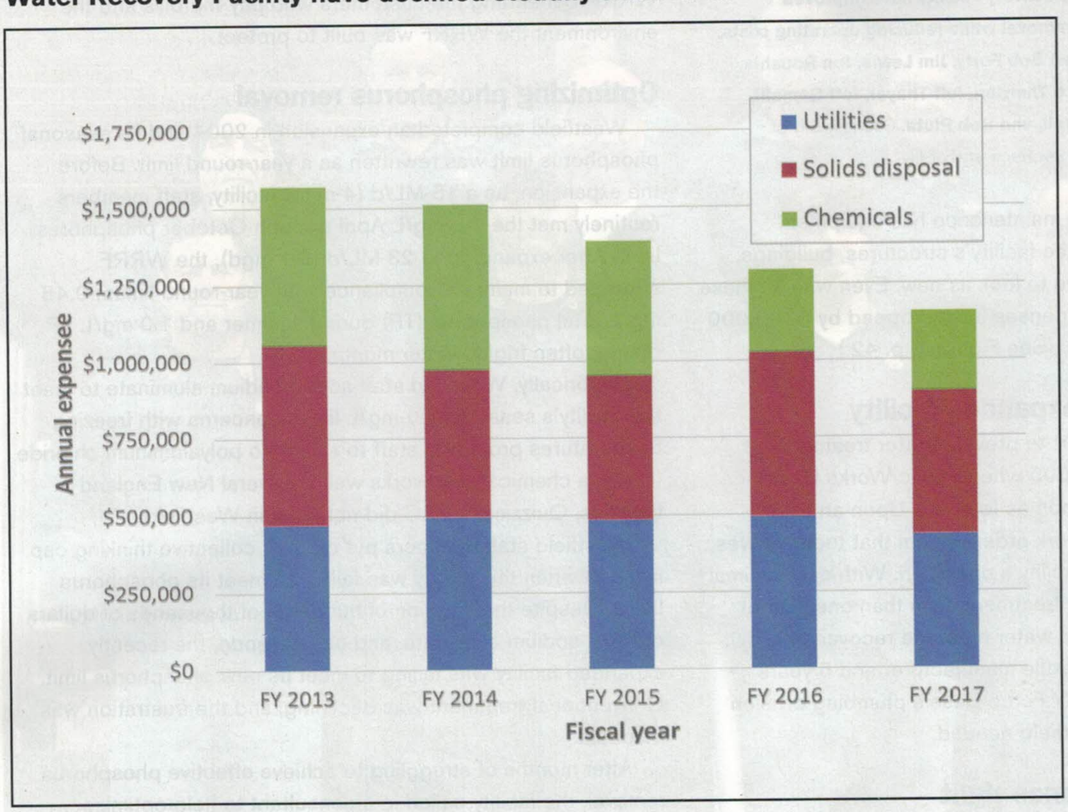
After months of struggling to achieve effective phosphorus removal, the facility called in a consultant to help optimize biological phosphorus removal (BPR) and polish with sodium aluminate. These process changes, some of which seemed risky at the time, were led by Jeff Gamelli, a recent graduate of the University of Massachusetts Amherst Civil Engineering School. Gamelli was hired as Gagnon's assistant in 2013. This task proved to be a great experience for Gamelli. With his hands-on understanding of the biochemical processes that drive wastewater treatment, he searched for ways to improve Westfield's effluent quality. (Three years ago, Gamelli was promoted to deputy superintendent of the facility.)

To enhance BPR, the first of three aeration passes in each treatment train were converted to fermenters by turning off aeration. To prevent solids from settling out of the mixed liquor, the two floor-mounted, fine-bubble aeration zones in the first section of the facility's three-pass aeration tanks were operated to mix with minimal oxygen transfer.

In the first zone, 90% of the membrane disk diffusers were removed and stainless steel screws inserted into the air outlets to seal off the airways. The remaining 10% of the diffusers were converted to big-bubble mixers by cutting large Xs into the membranes. Air to the second zone of the first pass is restricted by closing the butterfly valve on the aeration header so that a minimal amount of air passes through. Once per day, the valves in each train are opened fully for 15 minutes to thoroughly mix the tank contents.

To track phosphorus removal, the facility installed an in-line orthophosphate analyzer to continuously monitor final effluent levels and track results using the supervisory control and data acquisition (SCADA) system. The SCADA system was programmed to provide real-time and historical orthophosphate (ortho-P) data as well as a method to predict TP, which is the

Figure 1. Operating expenses at the City of Westfield Water Pollution Control Water Recovery Facility have declined steadily since 2013



specific parameter listed in Westfield's permit. The SCADA system converts ortho-P – the soluble fraction of phosphorus – to TP using data from an in-line effluent TSS probe. Given that the dry weight of Westfield's effluent TSS historically has been 3% phosphorus, the SCADA system adds 3% of the TSS probe reading to the ortho-P results to accurately approximate the effluent TP concentration.

To polish the TP concentration further, sodium aluminate is added to each train's aeration tank inlet. The chemical feed rate is set manually via the SCADA system and increases by 40% between 7 p.m. and 5 a.m. on specific days to compensate for the additional phosphorus loading that the SCADA trending charts show to routinely occur.

By analyzing the effluent ortho-P graph from the inline analyzer, staff discovered historical peaks of ortho-P concentrations at around 5 p.m. To identify the source, Gamelli back-calculated the hydraulic retention time of the system from the effluent to the beginning of aeration. These "peaks" of ortho-P coming through the beginning of the aeration tanks actually were passing through at about midnight, not noon. This led to the increase of sodium aluminate dosing at night to help polish phosphorous removal. As flows and loads increase during the day, BPR removal efficiency increases and sodium aluminate dosing is reduced.

Figure 2 (p. 43) shows how these changes have reduced TP effluent concentrations. These gains have happened at the same time that chemical and utility expenses have been dropping.

Overall, as staff gained control over phosphorus removal, things began to get interesting in Westfield. The work environment improved markedly. The changes made to bring the facility into compliance were scientifically sound, but somewhat unconventional. Staff members enjoyed learning about the biochemistry and experimenting with process changes to create optimal habitats for the bacteria that remove the waste from wastewater. A "we can do better" attitude developed.

Dialing-in nitrogen removal

Westfield staff members next set out to experiment with different ways of operating equipment. The more they experimented, the more control they gained. Although some experiments were abject failures, none created compliance issues.

Conveniently, the Westfield facility is split into three identical, but separate, parallel treatment trains. Even the return activated sludge (RAS) from secondary clarifiers is independently returned to its companion aeration tank. This arrangement has its pros and cons, but for the creative types employed at Westfield, the arrangement enables any one train to operate as a full-scale pilot.

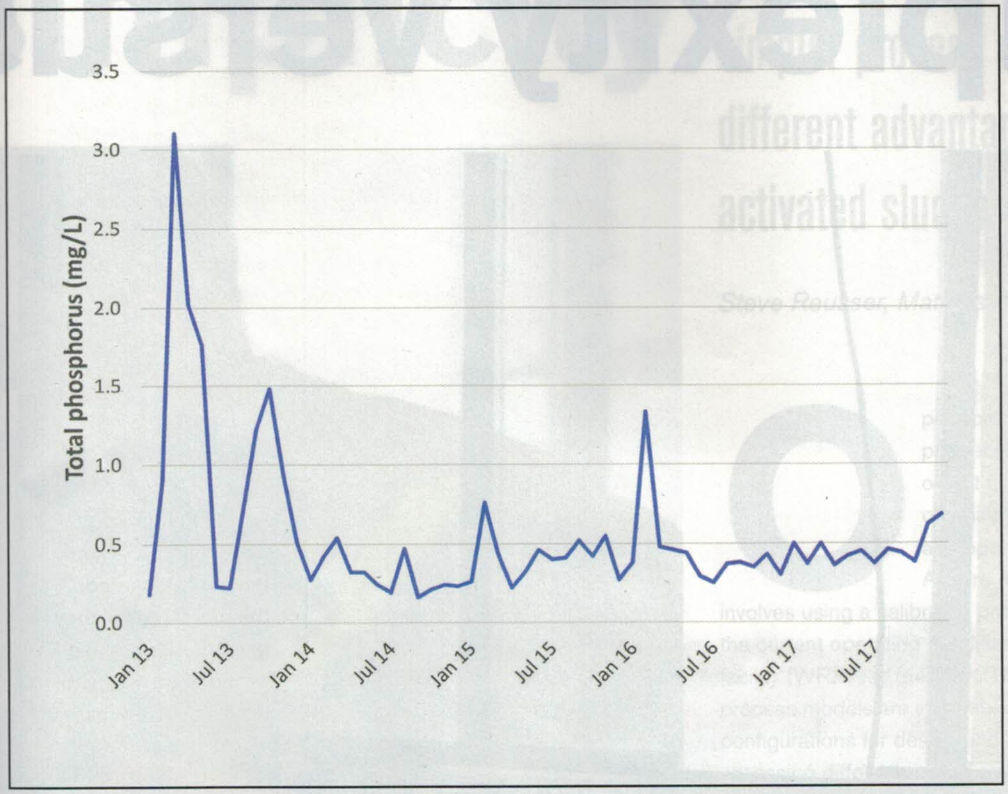
Staff were aware that the creation of fermentation zones at the inlet end of the aeration tanks improved nitrate removal (a good thing), but the nitrate removal in these zones interfered with BPR (a bad thing). They experimented with process changes to remedy the issue.

In one experiment, a primary clarifier was converted to a fermenter. Waste sludge was pumped to the primary clarifier to provide phosphate accumulating organisms (PAOs) and supplemental BOD to drive BPR. During the experiment, no sodium aluminate was added to that train's aeration tank. Effluent phosphorus was quite low, but the aeration tank mixed liquor suspended solids (MLSS) rose to such high concentrations – 8000 mg/L – that the solids flux overwhelmed the secondary clarifier to the point where flow through that train had to be restricted. This produced great results, but not a process change that could be applied to the whole facility without creating effluent TSS issues.

In another experiment, the aerobic portion of an aeration tank was operated as a sequencing batch reactor to nitrify during an air-on cycle and denitrify during an air-off cycle. Nitrogen removal improved markedly, but BPR declined.

Additionally, a diesel-powered trailer pump was used as an internal recycle pump to convey nitrate-rich flow from the aeration tank outlet to the inlet end of the air-off second pass.

Figure 2. Total phosphorus effluent concentrations have dropped and steadied at the City of Westfield Water Pollution Control Water Recovery Facility



A small reduction in nitrate was observed, but the pump didn't have sufficient capacity to support complete denitrification: BPR suffered.

As an energy savings measure, Public Works Director Dave Billips arranged to replace Westfield's three oversized, vintage, centrifugal blowers from 2004 with three positive displacement blowers. This upgrade has shown a consistent monthly savings of $5000 and reduced the facility's electrical consumption by 20%.

After the new aeration equipment was installed and debugged, staff experimented with using an in-line ammonia analyzer to control blower operations, implementing ammonia-based aeration control (ABAC) with in-house ingenuity and the help of the SCADA integration company, Aaron Associates (Waterbury, Conn.). The preliminary ABAC results have shown a 50% reduction in air flow requirements. The ABAC proportional–integral–derivative (PID) control loop trims the dissolved oxygen (DO) set point depending on the ammonia concentration leaving the aeration basin. If the ammonia concentration is below the average set point, then the DO set point is trimmed down, and vice versa. This change is anticipated to create a further 20% reduction in electrical use.

From these experiments, staff have learned how their WRRF responds to various process changes. These operators are uniquely positioned to oversee any facility upgrades that may be required to meet more restrictive nutrient limits. For now, the facility operates with several customizations to improve performance:

- MLSS is 60% higher than what it was before optimization (4500 mg/L vs. 2800 mg/L).
- Airflow is minimized in the first pass of each aeration tank to create fermentation zones for VFA production and PAO uptake.
- The fermentation zones also enhance denitrification for improved total-nitrogen removal.

Periodic testing with a portable oxidation–reduction potential (ORP) meter confirms that optimal conditions are maintained in the pre-anaerobic zones. In-line ORP probes monitor process conditions at the end of the aeration tanks. The data routinely are compared to efficiencies in BOD and TSS removals and nitrification optimization.

Monetary savings

Electrical, chemical, and solids disposal expenses have been on a steady decline since 2013 as shown in Figure 1 (p. 42). Chemical costs are now half of what they were 5 years ago. Sludge disposal costs are down by more than $100,000 per year. Utility savings of approximately $60,000 per year are being realized.

Total operating expenses (not counting capital and debt service expenditures) have seen a decline from $2.85 million in fiscal year 2014–2015 to $2.66 million in fiscal year 2016–2017. Staffing (labor and benefits) costs have decreased by $20,000. Chemical and electrical savings help lower operational costs and provide for more sustainable treatment.

Experimentation is the new norm

After a struggle to dial in year-round phosphorus removal, the Westfield staff has become empowered. The facility was not designed for year-round phosphorus removal and its operation and maintenance manual didn't provide guidance on how to do it. Rather than seeking design engineering support, the facility staff sought operational support and began a journey that has them using equipment in ways never envisioned in the design process.

Thanks to the good work of the design engineers, flexibility was built into Westfield's facilities. Using this flexibility has enabled the operators to achieve continually better and better treatment results over the years.

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