OPERATOR PERSPECTIVES

Empowering wastewater operators to excel

GRANT WEAVER, PE, Wastewater Operator, President, CleanWaterOps, Boston, Massachusetts

After decades of promoting technological innovation as the solution for water resource recovery facility (WRRF) permit requirements, an increasing number of organizations—including EPA, WEF, and numerous state and local government entities—are recognizing the role that informed, empowered WRRF operators play in making the nation's waterways ever cleaner.


Ken Lord, Palmer


Jeff Gamelli, Westfield

This increasing awareness comes when thousands of inexperienced operators are being hired to staff the nation's 18,000 municipal WRRFs. The Municipal Association of South Carolina quotes the American Water Works Association as stating that one-half of the nation's wastewater operators will retire by 2021. Meanwhile, the passing rate for higher levels of wastewater licensing is commonly 50 percent or less in many New England states. Is this a crisis? Or is it an opportunity?

Informed operators make a difference! The following tables of Montana wastewater treatment facilities show that skilled operators can improve water quality cost-effectively.

With training and encouragement, the operators of the conventional WRRFs in Table 1 achieved the same level of nitrogen removal as operators at facilities designed for nutrient removal (Table 2), at a fraction of the cost.

As the accompanying case studies illustrate, similar improvements in nutrient reduction have been achieved at several New England WRRFs. These case studies support the same conclusion: an empowered workforce can often provide more cost-effective permit compliance than can facility upgrades. With the recent need to remove nutrients and other pollutants, along with an aging workforce and high staffing turnover, the time for educating, empowering, and expecting more from WRRF operators is now. A small change in State Revolving Fund (SRF) policy to allow state regulators to allocate up to one percent of their state's annual SRF appropriations to viable education programs would provide resources for much-needed process control training and technical support.

Table 1. Optimized conventional WRRFs in Montana*

	Design Flow	Total Effluent-N	Total Effluent-P
Chinook	0.5 MGD (1.9 ML/day)	3 mg/L	1.2 mg/L
Conrad	0.5 MGD (1.9 ML/day)	7 mg/L	0.1 mg/L
Hardin	1.0 MGD (3.8ML/day)	5 mg/L	2.4 mg/L
Hamilton	2.0 MGD (7.6 ML/day)	3 mg/L	4.0 mg/L

Combined cost of optimization: $20,000

Table 2. Montana biological nutrient removal facilities*

	Design Flow	Total Effluent-N	Total Effluent-P
Bozeman	8.5 MGD (32 ML/day)	5 mg/L	0.3 mg/L
Missoula	12 MGD (45 ML/day)	9 mg/L	0.2 mg/L
Kalispell	5.4 MGD (20 ML/day)	8 mg/L	0.2 mg/L
Lewistown	1.5 MGD (5.7 ML/day)	2 mg/L	1.0 mg/L

Combined cost of facility upgrades: $70 million

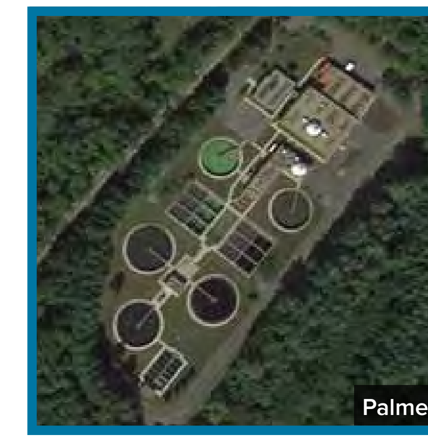
*Lavigne, P. & Weaver, G. (2017) Enabling operations; creative operational strategies as a stand-alone approach to significant nutrient reduction. Water Environment & Technology, 29(12).

Frequently, the biggest obstacle to capturing the potential that talented and experienced operators provide is an abundance of well-intended regulatory policies and procedures that overlook the good work being done at the front line of pollution control. As we seek to empower operators, a discussion of how regulatory efforts to support innovation by changing years of regulatory status quo is in order.

Historically, the regulatory standard has been a pass/fail system of permit compliance (pass) and non-compliance (fail). Nearly all our regulatory resources have been applied to issues of non-compliance, leaving it up to operators to optimize their facilities themselves. Operators, however, are generally risk averse. Once a WRRF has been "dialed in" and permit compliance becomes routine, it often takes encouragement for an operator to experiment with process changes. In a pass/fail regulatory environment, little incentive exists to make modifications that may improve operations. Historically, operators have understandably been more concerned about risking permit violations than achieving excellence.

In the past, many regulatory organizations have inadvertently discouraged innovation by requiring that each component of a WRRF be operated in accordance with the operation and maintenance (O&M) manual prepared at the time of construction. These policies were enacted to ensure that the public's investment was not squandered. However, the practical outcome is stagnant plant performance. For example, conventional plants must be operated for conventional treatment and not for nutrient removal.

Ken Gagnon, Westfield


Palmer

CASE STUDIES

Palmer, Massachusetts (population: 12,000)

Prior to any optimization, the blowers at the 5.6 mgd (21 ML/d) Palmer Water Pollution Control Facility (WPCF) were equipped with variable frequency drives (VFDs), and the blower speeds were controlled by dissolved oxygen (DO) probes in the aeration tanks. Under the direction of Superintendent Gerry Skowronek and Assistant Superintendent Ken Lord, timers were installed on the aeration blowers, and oxidation reduction potential (ORP) probes were installed in both the in-service complete mix aeration basins.

Believing it possible to provide total-nitrogen (TN) removal more cost-effectively than the $320,000 facility modifications described in a 2015 NEIWPCC study, *Low Cost Retrofits for Nitrogen Removal at Wastewater Treatment Plants in the Upper Long Island Sound Watershed*, the Palmer WPCF operators cycle the one in-service blower on for 4 to 6.5 hours and off for 3 to 4 hours. The ORP probes monitor only; the results are reviewed every two weeks and the air-on/air-off times are adjusted to provide a peak ORP of +150 mV for ammonia oxidation to nitrate and a minimum ORP of –100 mV for nitrate removal. Weekly effluent lab results confirm the appropriateness of the ORP targets and the air-on/air-off settings.

Over the past three years (2015 to 2017), effluent TN averaged 8.9 mg/L. Prior to optimization (2010 to 2013), TN averaged 17.8 mg/L.

Biological phosphorus removal is enhanced by recycling waste activated sludge (WAS) through the facility's gravity thickener and into aeration. Phosphate accumulating organisms (PAOs) that live in the aeration tank mixed liquor, and therefore in the WAS, are subjected to anaerobic conditions in the gravity thickener. There, volatile fatty acids (VFAs) are formed and consumed by the PAOs. A percentage of the waste sludge is pumped back to the influent daily. As they migrate through the aeration tank, the energized PAOs pull soluble phosphorus out of solution.

By optimizing biological phosphorus removal, Palmer has met its 1.0 mg/L total-phosphorus (TP) limit using one-third the chemicals used prior to optimization. Given the low alkalinity of the WRRF's wastewater and the

A small change in State Revolving Fund (SRF) policy to allow state regulators to allocate up to one percent of their state's annual SRF appropriations to viable education programs would provide resources for much-needed process control training and technical support.

Additionally, modifications to O&M manuals had to be written by engineers; the operator's role was to follow direction, not seek new and better ways of getting the job done. Now, progressive regulators are looking at O&M manuals more as owner's manuals, similar to those in the glove boxes of our cars. The modern regulatory position is to view O&M manuals as an invaluable resource containing information on the facilities we operate but of no value regarding process control. O&M manuals should not dictate how wastewater treatment facilities are operated; facility operations should instead be based on the experience of the facility operators.

Informed regulators encourage operators to strive for excellence. As the front line in water quality protection, operators—their risk-averse nature notwithstanding—all take pride in doing good work. The first regulatory hurdle, therefore, is to change policies and procedures that inhibit operator creativity. Of paramount need is a revision of those policies and procedures that give higher operational standing to people who design WRRFs than to those who operate them.

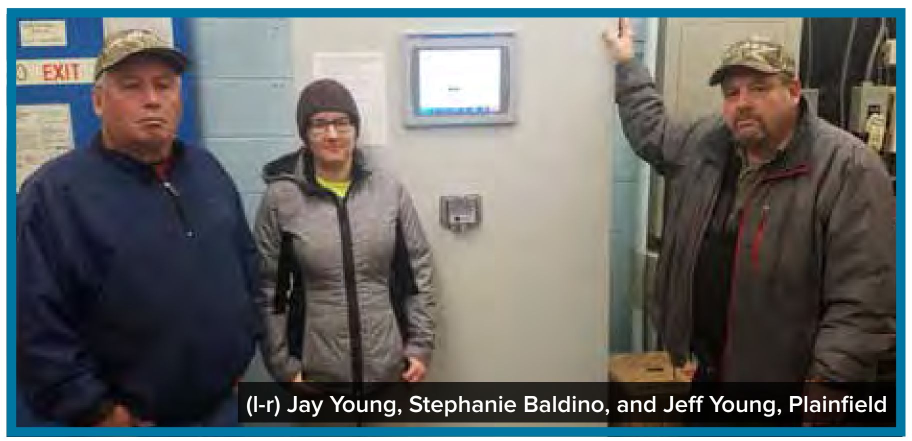
Operators like making clean water. I have yet to meet anyone in our profession who would prefer to make dirty water than clean. In working with the staffs of more than 60 municipal WRRFs, my experience is that informed changes in day-to-day operations significantly reduce nitrogen and/or phosphorus at most treatment plants, whether they are designed for biological nutrient removal or not. Usually, water quality can be improved with operational cost savings from reduced electricity consumption, fewer chemicals, and less sludge processed and hauled offsite.

Those who work at WRRFs are, if anything, reclusive, and certainly not glory seekers. Since most publicity surrounding facilities is bad (e.g., odors and rate hikes), operators generally like staying well under the radar and out of the limelight. Most operators see or hear from their regulators only during plant inspections. And most like it that way. Most regulators focus on paperwork and laboratory procedure rather than providing practical guidance for improved plant operations, likely because many inspectors do not hold an entry level license, let alone the higher levels of licensing required to oversee most facilities. Given that most inspectors have visited far more WRRFs than most operators, this is an opportunity lost.

The more successful regulatory agencies are correcting this. Their inspectors do not hide from their limited operational experience; instead they actively participate in classroom training alongside the operators of the facilities they oversee. As they learn new operating strategies together, partnerships develop and, before long, inspectors become valued for transferring knowledge from WRRF to WRRF. A particularly valuable form of training is morning classroom sessions on process control strategies (for example, nitrogen or phosphorus removal) followed by afternoon sessions in which operators talk about their plants and brainstorm ideas with their fellow operators (and regulators!) on how to make their facilities operate more effectively and efficiently.

When new standards are written into discharge permits, regulators typically include an implementation timeline that begins with the employment of a design engineer and ends with the construction and operation of new equipment. Such a timeline all but forces new construction, regardless of cost or environmental impact. Because construction funds are in short supply, priority points are awarded to determine which


Aaron Costa, Keene



(l-r) Jay Young, Stephanie Baldino, and Jeff Young, Plainfield


Westfield


Edward Davenport & Jay Young, Plainfield

recent increase in the cost of pH-adjusting chemicals, of late Palmer finds it more economical to cut back on the caustic soda needed to maintain an optimal aeration tank pH of 7.0 for biological phosphorus removal in favor of using more poly-aluminum chloride (PAC) to precipitate phosphorus.

Westfield, Massachusetts (population: 41,100)

Starting on December 1, 2009, Westfield had to meet a year-round phosphorus limit (0.46 mg/L in summer and 1.0 mg/L in winter). Historically, plant staff of this 6.1 mgd (23 ML/d) facility added sodium aluminate to meet the 0.46 mg/L limit for April through October. Concerns about freezing prompted staff to switch to polyaluminum chloride, a chemical that has worked well in several facilities (including Keene, New Hampshire). After months of struggling to achieve effective phosphorus removal, staff switched back to sodium aluminate and began exploring options for maximizing biological phosphorus removal.

Thus, over the last five years Jeff Gamelli, Ken Gagnon, and staff have undertaken various process changes with the support of Public Works Director David Billips. These changes have not only brought the facility into compliance with tighter phosphorus limits, they have also reduced operating costs and provided other water quality improvements.

The plant's O&M budget for fiscal year 2018 was $5.2 million, a 7 percent ($400,000) reduction from $5.6 million in fiscal year 2016. Savings in chemical costs ($200,000 per year), electricity ($70,000 per year), and sludge processing and disposal ($150,000) have been achieved.

The facility is operating with a higher mixed liquor suspended solids [MLSS, (4,500 mg/L)]. Airflow is minimized in the first pass of each of the plant's three trains to create fermentive zones for VFA production and PAO uptake of VFAs. These fermentation zones also enhance denitrification for improved TN removal.

The two floor-mounted fine-bubble aeration zones in the first of the plant's three-pass aeration tanks are uniquely operated to provide mixing with minimal oxygen transfer. In the first zone, 90 percent of the membrane disk diffusers have been removed and stainless steel screws have been inserted into the air inlets to seal off the airways. The remaining 10 percent of the diffusers were converted to big bubble mixers by cutting large Xs into the membranes. Air to the second zone is restricted by partially closing the knife valve on the aeration header. Once per day, the valve is fully opened for 15 minutes to thoroughly mix the tank's contents.

An in-line orthophosphate analyzer monitors effluent soluble phosphorus, and an equation programmed into the plant's supervisory control and data acquisition (SCADA) computer factors in the effluent total suspended solids (TSS) concentration obtained by an in-line TSS probe to compute the theoretical TP concentration. To get TP, TSS is multiplied by 0.03 and added to the ortho-P reading.

Periodic testing with a portable ORP meter is performed to confirm conditions in the pre-anaerobic zones. In-line ORP probes monitor conditions in the aeration tanks. After successfully testing an in-line ammonia analyzer in one aeration zone during the summer of 2017, three in-line ammonia analyzers will be installed in 2018. A 20 percent reduction in electrical use is anticipated.

Westfield's effluent phosphorus limits are routinely maintained. The year-around average for 2017 was 0.43 mg/L. In 2013, effluent TP averaged 1.1 mg/L. Effluent nitrogen is now averaging 8.1 mg/L for 2017. Prior to optimization (2010), TN averaged 13.9 mg/L. Conventional treatment has likewise improved. TSS and BOD averaged 4.7 mg/L and 6.6 mg/L, respectively, in 2017. In 2010, TSS averaged 7.1 mg/L and BOD averaged 9.5 mg/L.

Keene, New Hampshire (population: 23,500)

To meet the water resources recovery facility's (WRRF's) interim copper limit of 20 ug/L, Keene had already been adding PAC to the aeration tank effluent/secondary clarifier inlet since 2005. In 2008, to meet an interim TP limit of 0.5 mg/L during summer, PAC was added in two places—the inlets to both the primary and secondary clarifiers. Approximately 300 gpd (1100 Lpd) of chemical was required.

After attending a 2009 EPA nutrient removal seminar in Marlborough, Massachusetts, plant staff attempted biological phosphorus removal at a plant not designed municipalities are to receive funding. Well-maintained, well-operated WRRFs frequently receive fewer points than struggling facilities, creating an incentive for municipal dependence on regulatory support and a disincentive for excellence.

Fortunately, there is a growing industry awareness of the value that operators bring to wastewater treatment. And regulators are responding by seeking new, productive ways to interact with those at the front line of water quality protection: wastewater operators.

EPA has prepared a voluntary survey due to be distributed to all publicly owned WRRFs in 2018. A draft was circulated in 2017. The survey will develop a database of facilities that are removing pollutants more effectively than what the facilities were designed to accomplish. In advance of the nationwide survey, a draft report, Case Studies on Implementing Low-Cost Modifications to Improve Nutrient Reduction at Wastewater Treatment Plants, has been prepared. It is currently under revision. A similar report by the New England Interstate Water Pollution Control Commission (NEIWPCC), *Low Cost Retrofits for Nitrogen Removal at Wastewater Treatment Plants in the Upper Long Island Sound Watershed*, was finalized in 2015.

The EPA and NEIWPCC reports provide case studies and site-specific recommendations on how WRRFs have been (or can be) modified to provide cleaner water at minimal cost. Additional case studies are available on the Internet, but, with so few companies providing the service, these reports can be difficult to locate.

Municipal wastewater discharge permits written by EPA Region 1 for western Massachusetts communities frequently contain language that requires the municipality to annually notify EPA and the Massachusetts Department of Environmental Protection (MassDEP) of changes to optimize nitrogen removal and to quantify the amount of nitrogen discharged compared to an annualized pounds per day target. Many municipalities have taken the challenge to heart and have experimented with process control changes to improve nitrogen removal. Among them are the following: Amherst's Duane Klimczyk; Easthampton's Carl Williams; Greenfield's Mark Holley; Montague's Bob McDonald; Northfield's Eric Meals; Palmer's Gerry Skowronek and Ken Lord; South Hadley's Mike Cijka and Melissa Labonte; and Westfield's Jeff Gamelli and Ken Gagnon.

Montana and Tennessee have taken the idea one step further. There, permits are requiring the preparation and submittal of nutrient optimization studies. The approach being used by EPA Region 1 in Massachusetts and by permit writers in Montana and Tennessee offers municipalities a choice: permittees are given the opportunity to seek operational changes in advance of numerical limits. If they choose to do so and are successful, they can delay or eliminate the need for facility upgrades. Meanwhile, those that choose to stick with the status quo always have the option of building new.

To empower operators to excel, regulators are transitioning from a pass/fail approach toward the wastewater treatment plants they oversee to a collaborative search for excellence. Historically, regulatory efforts were focused on non-compliant treatment facilities while WRRFs that maintained permit compliance received little attention. Now, as a "we expect excellence from our operators" regulatory policy is developing, regulators are taking on roles of mentors rather than rule enforcers. New England's waterways are benefitting from more operator training and technical support.

To bolster this success, we need better mechanisms for recognizing operator excellence. When so much good work falls under the radar, it can be hard to identify, acknowledge, and reward. Another low-profile issue is the shortage of operational consultants. An abundance of talented people populates the engineering community, but few want to transition from design work to operational support. There remains more work to be done.

for it. The first step was to shut off aeration in the first quarter of the 6 mgd (23 ML/d) facility's aeration train to create a pre-aeration fermentation zone for biological phosphorus removal. Mixing was achieved by operating a mechanical mixer. The experiment was successful and chemical consumption was cut in half, with one dose point eliminated.

With the combination of biological phosphorus removal and post-aeration chemicals, the effluent TP concentration dropped to below the 0.2 mg/L final limit, something chemicals alone did not achieve. An in-line orthophosphate analyzer was installed on the final effluent to allow staff to monitor the orthophosphate concentration on the plant's SCADA system.

As optimization progressed, a design study determined the best long-term strategy for phosphorus removal. An $18 million facility upgrade involving new clarifiers, additional bioreactor tankage, new chemical handling equipment, and final effluent filters was recommended as the best long-term strategy for phosphorus removal. Keene proceeded with a $12.8 million upgrade, investing $8.7 million in the WRRF, $1.6 million for a new pump station, and $2.7 million in dewatering.

Two new chemical handling buildings were constructed and equipped with bulk storage tanks, but no new clarifiers, tanks, or filtration equipment were built. Most of the money was used to repair and update equipment. For example, renovation of the WRRF's influent pumping station including new pumps, controls, and a complete electrical upgrade. At the WRRF, construction included a new electrical building, an electrical upgrade including all new VFDs and motor control centers (MCCs), and a new generator transfer switch. To replace the WRRF original generator, a new generator room was built.

Process upgrades included new return activated sludge (RAS) and WAS pumps and controls, new turbo blowers to replace two positive displacement blowers, and a new UV disinfection building and system. Upgrades to the clarifiers included larger scum boxes and algae sweeps. The plant's dewatering system was completely upgraded by replacing the belt filter presses with more efficient screw presses. The phosphorus removal upgrade was about 28 percent of the overall project cost.

Keene staff's innovative efforts have resulted in eight years of compliance with a summertime 0.2 mg/L TP limit at a fraction of the capital cost of the initial design. By not having to invest in new clarifiers and modifications to the biological reactor or construct and purchase a filtration system, the city used the money to upgrade and replace aging infrastructure at the end of its useful life, something that would have been needed regardless.

Plainfield, Connecticut (population: 15,400)

After a decade of study, a 2010 report recommended replacing Plainfield's 0.707 mgd (2.68 ML/d) Village plant with a new pumping station and force main. The study called for the replacement of the town's 1.08 mgd (4.09 ML/d) North plant with a new sequencing batch reactor (SBR). Both WRRFs were constructed in the 1970s and in need of renovation. Neither was designed for nutrient removal. The total cost of the recommended repairs was $50 million.

As the design report was being prepared, town staff led by Superintendent Jeff Young and Chief Operator Jay Young, began making process changes at both facilities. They were motivated by Connecticut's nitrogen trading program to reduce nitrogen credits purchased by the town, resulting in significant cost savings. Within months, effluent TN had dropped considerably at both facilities. The larger North plant's TN concentration declined from 18 to 10 mg/L while TN at the Village plant dropped from 14 to 8 mg/L. Process changes also resulted in a measurable drop in phosphorus at the Village plant, from 2.6 to 0.8 mg/L. BOD and TSS removals were unaffected.

By 2012, the process changes had proven effective and plant staff became confident that their WRRFs could meet future permit requirements. In lieu of the recommended $50 million upgrade, the town self-financed a $5.5 million renovation of the two treatment facilities. New aeration equipment, disinfection equipment, and simplified computer systems were installed at both plants. To meet a 1.09 mg/L TP limit, chemical phosphorus removal equipment was installed at the Village plant. The process changes are described below.

The four mechanical aerators at the North plant (with two aerators in each of the two parallel trains) were cycled on and off to provide periods of aeration for ammonia conversion to nitrate. Aerators were off for periods to provide sufficiently anoxic conditions to support nitrate conversion to nitrogen gas. The tank contents were not mixed during air-off conditions. Portable meters logged ORP readings every 15 minutes on thumb drives. The thumb drives were removed weekly and the data downloaded tabularized, graphed, reviewed, and compared to daily test strip ammonia, nitrite, nitrate, and alkalinity results to establish the following week's air-on/air-off timer settings.

Instead of cycling the air on and off in the aeration tanks to create SBR-like cycling of aerobic and anoxic conditions at the Village plant, the aeration tanks were maintained sufficiently aerobic to provide consistent, effective ammonia conversion to nitrate. Nitrate was converted to nitrogen gas in the plant's gravity thickener. A surplus of sludge was wasted to the gravity thickener daily, the gravity thickener overflowed solids, and the denitrified solids were returned to the influent wet well. The gravity thickener was sufficiently oxygen-deficient to provide fermentive conditions that removed nearly all nitrate and two-thirds of the phosphorus.

| EMPOWERING WASTEWATER OPERATORS TO EXCEL |