Online Sludge Level Monitoring Supports Efficient Nutrient Removal

While the traditional biological removal process can be challenging, the Lexington-Fayette Urban County Government (LFUCG) in Lexington, Kentucky, has achieved consistent success at its West Hickman Creek Treatment Wastewater Treatment Plant. With minimal modification investment, the resourceful utility converted its primary clarifiers to biological phosphorus removal (BPR) and its two stage nitrification system to a single stage nitrification system.

The plant's innovative and flexible design – coupled with key online measurements including continuous monitoring of the final clarifier sludge level – has allowed the utility to improve throughput, reduce aeration energy requirements, eliminate chemical consumption, and increase aerobic nitrification rates. "We control the amount of nitrate and phosphorus leaving these clarifiers," affirmed Plant Superintendent Tim Bullock. "We've got it down to a science."

An on-line Hach Sludge Blanket Level Monitor with graphic display helps West Hickman Creek WWTP operators control sludge pumping to minimize phosphorus in final clarifier effluent. The sensor is mounted on a three-foot pivot for convenient retrieval.

Design cycles anaerobic and aerobic zones

The West Hickman Creek Treatment Plant, which receives a relatively consistent influent makeup of domestic sewage, has experienced a series of expansions since going online in 1972. In 2000, LFUCG began yet another enhancement to increase capacity to meet an anticipated expansion of service to communities beyond Lexington. Further, because residential encroachment had nearly obliterated the space buffer around the plant, odor had become an issue. Finally, enhancement was to address the phosphorus discharge limitation anticipated in the facility's next NPDES permit.

The economic and inspired solution of a single-sludge activated-sludge system was designed by Doug Ralston, President of RR Consultants, an engineering firm based in Lexington and specializing in water and wastewater design and construction services. He envisioned a West Hickman Creek WWTP plan that cycles bacterial biomass sequentially through anaerobic and aerobic environments to make most of the organic substrate available for phosphorus (P)-storing (polyphosphate) bacteria in the initial anaerobic zone. Subsequent use of phosphates in the aerobic zone would accomplish uptake – and removal – of phosphorus.

The West Hickman Creek WWTP fermentation zone created by conversion of primary settling tanks has a BPR volume of 1.448 million gallons. Hydraulic retention time (HRT) at 40% RAS rate is 44 minutes.

Initial fermentation

Ralston anticipated that if primary clarification could be eliminated, he could convert the existing primary clarifiers to BPR units. Installing new influent fine screens with screening conveyors and compactors, and converting the anaerobic digesters to aerobic sludge holding tanks, proved to eliminate the need for primary clarification – and its associated odor.

A pilot study using respiration equipment to determine oxygen uptake rates after fermentation showed the existing eight primary clarifiers would be adequate for use in BPR. A straightforward, low-cost conversion of the tanks to fermentation zones consisted of removing all existing primary clarifier equipment and adding submersible mixing units. These mixers maintain suspended solids in the mixed liquor of plant influent and return activated sludge (RAS).

In this volatile pathway, zero dissolved oxygen (DO) makes Biochemical Oxygen Demand (BOD) available. Operators monitor the oxidation-reduction potential (ORP), typically -150 mg/L or less at the end of the process. Phosphorus-accumulating organisms (PAOs) consume BOD, and in the process convert P to released phosphate (PO_4).

The conversion from two-stage treatment to a post-fermentation, single-stage nitrification was a simple process, involving installation of panel diffusers in the eight-tank, first aeration zone. The facility retained the existing, nine-inch-diameter flexible membrane diffusers in the second aeration zone. Blower capacity was adequate with one blower taken offline to provide air for the 33.8-MGD capacity upgrade.

Effective, efficient – and flexible

The plant realized the traditional benefits of BPR, including suppression of filamentous bacteria in favor of the flocculating bacteria that improve subsequent sedimentation and clarification. The BPR process also reduces the use of polishing chemicals for phosphorus removal and the alkalinity adjustment usually needed to restore levels consumed by chemical precipitation.

Implementing BPR and biological nitrogen removal together adds further efficiency. Removing some soluble organic substrate in the anaerobic zone improves nitrification rates in the subsequent aerobic zone. Facility discharge typically exhibits less than 0.8 mg/L total phosphorus, allowing compliance with the 1.0-mg/L limit imposed by the state in 2002. Ammonia nitrogen averages less than 0.2 mg/L. And, the facility reduced energy consumption by taking a 500-horsepower blower offline.

Further, LFUCG enjoyed a lower-than-projected cost of meeting its upgrade goals. The initial cost estimate for increasing the West Hickman Creek plant capacity from 22.4 MGD to 30 MGD was nearly $24 million. The upgrade achieved a 33.8-MGD capacity at a cost of $9.4 million, which also included other upgrades to belt filter presses, the chlorination system and contact tank, and the channel odor control system.

According to Ralston, the ability of operators to adjust the system for varying conditions is critical to successful process control. They rely on a continuous-reading analyzer that monitors nitrate, ammonia-nitrogen, and phosphate in BPR to control addition of chemical precipitants for phosphorus polishing as needed. Enlarged inlets to two of the fermentation tanks allow operators to close the other tank inlet gates for normal plant flows during periods when BPR is not necessary. A flow diversion box prior to BPR protects it and the first zone of aeration from high flows that can cause washout.

Online sludge blanket monitor saves time, BPR

Another vital element for control, according to Bullock, is the sludge blanket in the final clarifier. Proper sludge blanket depth prevents the sludge from 'going septic' and releasing phosphorus into the supernatant and effluent – effectively canceling out BPR.

To assure a sludge blanket depth of 1.5 to 2.5 feet, operators had used a traditional 'sludge judge' to probe the blanket every four hours, or every two hours during rain events. With a total clarifier surface area of more than 90,000 square feet, manual sludge blanket probing proved costly in operator time.

Bullock found a solution in the off-the-shelf, continuous-reading Hach Sludge Level Monitor that relieves operators from the repetitive manual measurements and improves sludge blanket surveillance.

"Near the end of 2002, we installed four of these monitors in four of the final clarifiers. I put them in service with appropriate settings and, basically, walked away," he said.

The sensors are positioned near the top of the tanks and apply ultrasonic detection to determine position of blanket top or bottom. This technique keeps the sensor from contacting sludge solids. An integral sensor wiper continually cleans the sensor detector window to eliminate interference from gas bubbles and fouling from film buildup, so little operator time is required to maintain accuracy.

"We've done very little with them since installation, except read them," Bullock reported.

"Plant operators check the monitor displays about 12 times daily. The monitor's graphic display shows them at a glance whether recirculation adjustment is needed to control the phosphorus and nitrate leaving the clarifiers. We particularly like the trending graphs for troubleshooting."

He further explained that sensitivity of the sensors is set for typical conditions: "When a rain event changes sludge blanket texture, the sensor is not reading within the blanket our selected threshold. However, compared to the alternative, this is a circumstance we can easily work around. Instead of adjusting sensor sensitivity during these episodes, the operators make intermittent manual measurements."

Ralston and Bullock agreed the online sludge blanket level monitor is key to the success of the unique West Hickman Creek Plant BPR process. "We haven't had any excursion of our 1-mg/L phosphorus limit since system deployment, and we attribute that in great part to the sludge blanket monitors," said Bullock.

Proven performance

He anticipates further optimization when the facility incorporates an automated control system that will accept output signals from the sludge blanket level sensors. Until then, operators manually regulate the final clarification process based on measurements they receive from the sensors.

"With strict budgeting, we're building this house a room at a time," Bullock said. "As our solutions prove themselves, we'll invest further in them. We're adding a few more of the Hach sludge blanket level monitors, including one for the gravity thickener to help control pumping there."

The West Hickman Creek Treatment Plant is one of the first plants in the country to apply this single-sludge single-stage nitrification process, and it continues to prove successful after more than four years' operation. The design is expected to be implemented in more treatment plants, including the second LFUCG Town Branch WWTP.

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