Tales from the Files of the Compliance Assistance Unit

Better Effluent, Less Cost: Alternative Operation for Biological Phosphorus Removal

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Nutrient reduction in wastewater treatment systems is becoming increasingly important as National Pollutant Discharge Elimination System (NPDES) permits become more strict and energy becomes more expensive. Many small communities are facing permit limits that their existing treatment systems were not designed to meet. New, expensive facilities are constructed and often the costs for energy and chemicals are much higher than expected, yet compliance with permit limits are not guaranteed.

The Village of Bradford constructed a new wastewater treatment plant in late 2013 to comply with a new total phosphorus (TP) limit and to eliminate combined sewer overflows in their collection system. The village constructed a biological nutrient removal wastewater treatment plant (WWTP) which came online in early 2014. Almost immediately, the treatment plant had difficulty attaining the 1 mg/L TP limitation in its NPDES permit. This was despite feeding alum prior to clarification. From 2014 through April 2018, the village met their permit only seven times in 48 months, approximately 14.5 percent of samples.

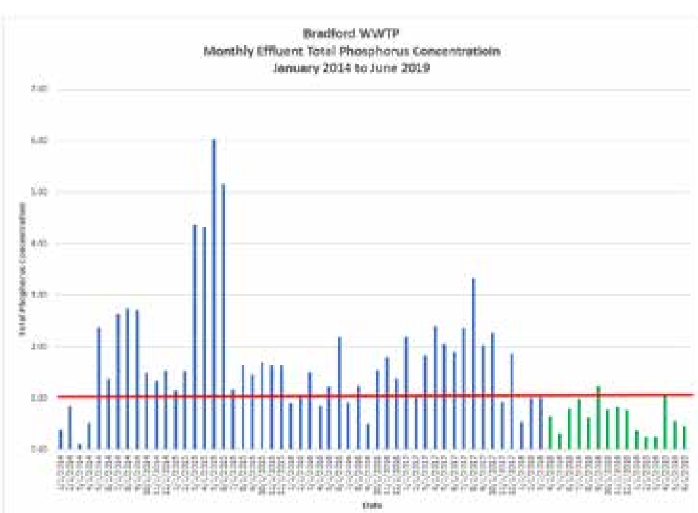

Figure 1: Total Effluent Phosphorus (Monthly Average 2014-2019)

Although Jay Roberts, superintendent of the Bradford WWTP, was skeptical, the village contacted Ohio EPA's Compliance Assistance Unit (CAU) for help in March 2018. The CAU provides hands-on assistance to communities that are experiencing noncompliance with their NPDES permits. The CAU prides itself on returning communities to compliance using process control methods to optimize the treatment processes rather than proposing construction remedies. Through cheap, easy and effective analysis techniques, the CAU can often determine the process-limiting factors and then devise a plan to overcome such factors and achieve compliance.

When the CAU arrives at a WWTP, we typically conduct a nutrient profile to see if the bacteria are performing as they should in each treatment tank. In Bradford, the profile showed that anaerobic tanks tested chemically identical to the anoxic tank which tested identically to the oxic tank. Each was full of nitrate at concentrations of 11-

Figure 2: Anaerobic Tanks (Mixers ON)

14 mg/L. The only tank that this amount of nitrate would be expected would be the oxic tank. The results indicated that the environment of the anaerobic and anoxic tanks would need to change.

In this instance, correcting the chemical environment in each of the treatment zones required nitrate management. The first step was to reduce the nitrate recycle into the anoxic tank from the oxic tank. The anoxic zone appeared to have more nitrate coming into it than could be denitrified with the available carbon in the influent waste stream. Jay and CAU decided to reduce the nitrate recycle in the anoxic tank significantly by nearly shutting off the gate from the oxic tank. We also slowed down the main rotor in the oxic tank by turning down the variable frequency drive, reducing the highly oxidized mixed liquor flow into the anoxic zone and the amount of nitrate in the return activated sludge (RAS) that would enter the anaerobic tank. These simple process modifications dropped the nitrate in the anaerobic and anoxic tank to approximately 6 mg/L NO3-N.

Since the desired result was not yet attained (near zero nitrate in the anaerobic tank, and not much more in the anoxic tank), the next step was to completely shut off the nitrate recycle from the oxic tank into the anoxic tank. This ensured that only the nitrate in the RAS would enter the anaerobic and anoxic tanks.

A second issue affecting the desired biological environments was that the soluble carbon loading in the raw wastewater was insufficient to drive the anaerobic zone truly anaerobic and to denitrify the nitrate in the anoxic zone. This issue called for more drastic measures: turn off the mixers in the anaerobic and anoxic zones. By cycling the mixers ON for 30 minutes and OFF for 210 minutes continuously, the CAU theorized that the biological solids would settle, and the aerobic bacteria would begin to lyse in the settled sludge blanket. The lysed bacteria would provide the soluble carbon to drive the fermentation reactions in the anaerobic zone and drive the denitrification in the anoxic zone. The CAU installed ammonium and nitrate probes (IQ SensorNet VARiON by YSI/Xylem) in the anaerobic and anoxic zone to monitor these nutrients. A week later, the effluent orthophosphate concentrations were within permit. But the village was still feeding alum to combine with the orthophosphate.

The CAU believed that the WWTP was performing well enough to stop the alum feed. But the plant was running within its concentration permit and Roberts was concerned that any change might jeopardize the new-found compliance. To give him some confidence, the CAU installed a composite sampler on the clarifier effluent so that the total phosphorus concentrations could be sampled, but not be reportable because the sample was not taken at the final effluent. Repeated samples from this internal location indicated that the treatment plant was meeting its total phosphorus limit even after the alum feed was shut off. Although it was not being run as designed, the treatment plant was meeting it NPDES permit limits.

The next step was to set up a process control scheme to monitor the ammonia, nitrate and orthophosphate in each of the zones. Using field analysis techniques on grab samples, Roberts performed ammonia, nitrate and orthophosphate analysis on each of the zones (anaerobic, anoxic and oxic) approximately three days per week to monitor the chemical environment.

To take advantage of simultaneous nitrification/denitrification in the oxic tank, the rotor, which was controlled by a variable frequency drive, was slowed down incrementally as long as the effluent ammonia remained very low, typically less than 0.2 mg/L NH3-N. This allowed denitrification to occur on the back side of the oxidation ditch, further reducing the nitrate loading on the anaerobic and anoxic zones. The process control goal was to keep dissolved oxygen concentrations to a minimum in the oxic tank, thus reducing the nitrates contained in the RAS that could poison the anaerobic zone. Ultimately the first cell of the anaerobic zone was mixed continuously with influent wastewater to denitrify the RAS nitrate, and the second anaerobic zone begins to release orthophosphate in the settled sludge during the OFF part of the mixing cycle. The orthophosphate release continues during the mixer OFF cycle in the large anoxic tank in the settled sludge blanket. The orthophosphate is then taken up by the phosphorus accumulating bacteria in the oxic tank.

Total phosphorus noncompliance at Bradford's WWTP very likely resulted from an insufficient and inconsistent soluble carbon loading from influent waste stream. The lack of this carbon loading caused the anaerobic, anoxic and oxic zones to become overwhelmed with nitrate. Running the anaerobic and anoxic mixers ON/OFF to deep cycle the mixed liquor created an environment in the settled sludge blanket to get the desired bacterial response. Turning down the VFD on the main oxic rotor allowed additional denitrification in the back side of the oxidation ditch, further reducing the nitrate being returned to the anaerobic zone.

Compliance with the Bradford WWTP NPDES permit for TP began during the second week of April. The monthly average concentration has been attained for 12 of 14 months since the operational change was initiated with just two monthly concentration violations in that interval. Note though that the compliance also included three additional loading violations for TP, due to the high influent flows that pushed the loading over the limit despite having a compliant concentration. The alum feed system was recently repaired to attempt to improve compliance with TP during particularly wet weather conditions.

Bradford has also saved up to $750-$1,000 per month on alum as well as on their energy consumption through efficient operation of the main oxic rotor at low Hertz and cycling the anaerobic and anoxic mixers only three hours every 24 hours. The wastewater treatment plant is putting out better effluent at a significant operational cost savings.

If you have questions about operation at your facility, or would like more information about the CAU, visit our website (https://epa.ohio.gov/defa/CAU) or contact me at (614-580-5069).

Figure 3: Nitrate Recycle Gate Closed