Blue Lake Wastewater Treatment Plant
Shakopee, Minnesota

BACKGROUND: The Beginning of Blue Lake

In the 1950s, several major communities built wastewater treatment plants (WWTPs) to abate the effects overloaded septic systems were having on Lake Minnetonka, the state of Minnesota's tenth-largest lake. But by the late 1960s, the lake was receiving 3 million gallons of treated wastewater each day from several dysfunctional plants, and nutrient overload was causing deterioration of the lake's water quality.

In response to the *Clean Water Act* in 1972, the Blue Lake Wastewater Treatment Plant was built, now owned and operated by the Metropolitan Council Environmental Services (MCES). The initial phase of the plant included an aerated pond, disinfection and an effluent pump system. A second phase added bar screens, primary clarifiers and secondary treatment. In the late 1980s, in response to increasingly stringent water quality standards, a major expansion and upgrade project removed ammonia nitrogen, dechlorinated the effluent and increased dissolved oxygen in the effluent to combat low-flow oxygen sags in the river. The expansion included a levee expansion, bar screens, primary clarifiers, aeration tanks, secondary clarifiers, effluent pumps and a cascade aeration system. The aeration tanks featured a three-pass, tapered aeration system with fine bubble ceramic diffusers.

The plant was built on a floodplain, and a levee surrounds it to protect against flooding of the Minnesota River. However, the rock below the plant is fractured, so a groundwater dewatering system was installed to prevent damage to the wastewater tanks and service tunnels from uplift forces. Four 100-foot deep wells were installed in the early 1990s. Although the Minnesota River had not experienced significant flooding since 1965 and 1969, a few months after the new pumps were installed, repeated severe rainstorms saturated the ground, resulting in a 50-year flood in July of 1993. Another comparable record flood occurred in April of 1997. The effluent pump system and new dewatering pumps operated well, but groundwater levels were higher than targeted. Additional dewatering capacity was needed, and new and modified wells were added in 2008 to effectively protect the plant.

LIQUIDS TREATMENT

PHOSPHORUS REMOVAL

As part of the reissued permit in 1997, MCES was asked to voluntarily modify the process to accomplish enhanced biological phosphorus removal (EBPR), to the extent possible, without jeopardizing other treatment functions. In 2003, MCES retrofitted the first half of Pass 1 for each of the eight aeration basins with an MCES custom-made, four-hole flexible membrane diffuser creating an air mixed quasi-anaerobic selector without a baffle. Operations with the quasi-anaerobic selector showed the plant could reduce annual TP discharges below its proposed permit limit of 1 milligram per liter (mg/l).

In 2009, EBPR was improved by the installation of air control valves and baffles to isolate the anoxic zone and better control dissolved oxygen throughout the activated sludge process. New coarse bubble diffusers for the anoxic zones and replacement fine bubble diffusers for the aerobic areas were installed. A supplementary ferric chloride chemical feed system was installed to "trim" excess phosphorus, if needed, to consistently meet the 1 mg/L limit.

Influent junction structure. Blue Lake operating data showed unequal organic loadings to the east and west primary clarifiers. All recycles were routed downstream of the primary clarifiers, and inadequate mixing of flows in the influent junction structure (IJS) upstream of the bar screens caused the influent loading unbalance. The IJS configuration resulted in lower organic loadings in the east primary clarifiers because these clarifiers received a greater proportion of flow from areas with higher infiltration and inflow. The uneven loadings to the primary clarifiers carried forward to the aeration basins, which caused treatment performance to vary for each aeration basin. This varied performance made additional operational attention necessary and decreased system capacity. To maximize system capacity and optimize plant operations, computational fluid dynamics (CFD) modeling was conducted to develop a passive system that would thoroughly mix the incoming interceptor flows and equally distribute the influent loadings. The solution was to add a passive mixing pipe chamber upstream of the IJS.

Enhanced biological phosphorus removal. The Blue Lake WWTP was a nitrifying, air-activated sludge plant that was upgraded for EBPR. Prior to the improvement projects, the plant operated in a quasi-EBPR mode by reducing the airflow rate to the first half of Pass 1. The success of these initial operations prompted a three-month program to determine whether an air-mixed selector configuration could meet a 1 mg/L effluent total phosphorus (TP) level under projected future loading conditions and whether there was a quantifiable difference in phosphorus removal performance between a bioreactor configured with a baffled, mechanically mixed selector and an air-mixed selector. Full-scale testing showed that the air-mixed selector configuration reliably produced effluent TP concentrations averaging 0.1 to 0.34 mg/L of phosphorus under current and simulated Year 2020 influent loadings while maintaining complete nitrification. Comparison of the testing results with the effluent quality predicted through the BioWin model showed that the effluent TP concentration was not affected by the air-mixed selector configuration. On the basis of the testing results, each aeration basin selector zone was constructed using coarse bubble air delivered from 38 custom-fabricated diffusers located along the sides of the first half of Pass 1, selector zone air flow control values to control the mixing airflow rate, and a fiberglass reinforced plastic (FRP) baffle wall.

Secondary clarifiers. Addition of anaerobic digesters to the plant flow scheme significantly increased the loadings to the biological nutrient removal (BNR) system. To maintain the rated plant capacity, two improvements to the BNR system were necessary. First, the addition of the anaerobic selector improved sludge quality so that the plant could carry higher solids inventory to offset the loss in aerobic volume. Second, the secondary clarifier solids loading capacity was increased 50 percent by increasing the return sludge pumping capacity from 28 million gallons per day (mgd) to 50 mgd. To increase the sludge pumping capacity, the existing return activated sludge (RAS) pumps were replaced with two RAS pumps per clarifier. Under normal operations, one of the two pumps is operating, and during peak flows, the second pump is turned on to provide the needed capacity to prevent sludge blankets from rising.

Disinfection. Before 2010, the plant used gaseous chlorine and sulfur dioxide

Aeration basin air mixed selector zone.

bisulfite for disinfection and dechlorination. MCES management decided that all plants would convert from gaseous chlorine disinfection to a less hazardous system such as sodium hypochlorite or ultraviolet (UV) disinfection. A detailed evaluation of sodium hypochlorite/bisulfite, UV disinfection and a combination of the two technologies showed sodium hypochlorite/bisulfite to be more cost-effective than the combination system. The UV system could not be implemented without adding an intermediate pumping system.

The new disinfection system would reuse the existing disinfection building to house four 5,000-gallon sodium hypochlorite tanks, two 5,000-gallon sodium bisulfite tanks and their associated feed equipment. The primary challenge with implementing the new system was to coordinate construction so that the new system could be built and fully operational within the five-month non-disinfection season. Demolition of the existing building commenced in November 2009, and by April 2010, the new disinfection system was operational. The resulting facility features a disinfection system that uses fewer hazardous chemicals for plant operations but has higher operating costs than the former facility. The conversion also reduces the security and reporting required when gaseous chlorine cylinders tanks are on-site.

Additional improvements. Additional facility improvements were made to rehabilitate and replace existing equipment in the primary clarifier areas; heating, ventilating, and air conditioning (HVAC) systems; instrumentation and controls; and electrical systems. Other improvements were replacement of the existing one-inch bar screens with half-inch bar screens for two of the four units and

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Anaerobic digestion complex.

addition of a screening compactor. These improvements will reduce downstream maintenance costs, increase screenings capture and reduce screenings operations and disposal costs.

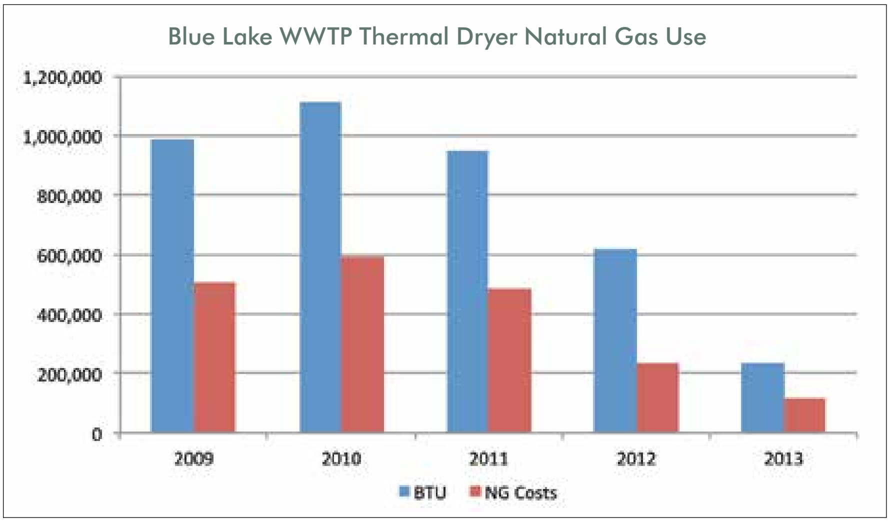
SOLIDS TREATMENT

The Blue Lake WWTP has eight 80-foot diameter primary clarifiers and four 50-foot diameter gravity thickeners for collection and thickening of primary sludge.

Waste-activated sludge collected from secondary clarifiers is thickened with gravity belt thickeners and then combined with the thickened primary sludge in a thickened sludge wet well.

For the first 28 years of operation, thickened, liquid sludge was trucked to the Seneca WWTP 15 miles away for incineration. To eliminate the transportation cost and begin beneficial reuse of the biosolids, on-site final stabilization facilities were installed at Blue Lake in 2000. Thickened primary and waste-activated sludge was dewatered using two new centrifuges, then processed through a thermal rotary drum dryer system to produce pellets for distribution as a fertilizer. A primary sludge screening system was installed to remove trash and debris to produce a cleaner pellet product. The dryer consumed significant amounts of natural gas as a fuel and did not have storage to allow the dryer to be out of service for maintenance.

An anaerobic digestion facility was constructed and brought online in 2012, primarily to reduce the amount of solids to be processed and to generate beneficial digester gas for the thermal dryer. The facility has a current capacity of 50 dry tons per day (dtpd) but was constructed to allow additional future capacity of 75 dtpd. The anaerobic digestion facility provides two-stage mesophilic digestion and consists of two primary digesters, followed by one secondary digester and a sludge storage tank. The storage tank and the individual digesters are 1.4 million gallons each. The digesters have fixed steel covers, and the storage tank has a flexible membrane cover. The primary heat source for the digesters is waste heat from the thermal dryer's wet scrubber. The secondary heat source for the digesters is hot water boilers that transfer heat to the sludge using spiral heat exchangers. The tanks are all equipped with a pumped mixing system.



Decrease in thermal dryer natural gas use after start-up digestion facilities and utilization of digester gas in dryer in 2012.

Sludge transfer between the tanks can occur by pump or gravity overflow.

The sludge storage tank allows storage of both digested sludge and digester gas. Digested sludge is pumped to the dewatering centrifuges on a continual basis. Anaerobically digested and dewatered sludge is then processed by the thermal dryer to produce pellets for distribution.

Digester gas is collected and stored in the storage tank. The flexible membrane cover ensures a constant pressure for the digester gas. The primary use of the digester gas is as a fuel for the thermal dryers. As a secondary option for use of the digester gas when the thermal dryer is not in service, Blue Lake is currently configuring the boilers to use digester gas to heat the digester sludge. If the dryer or the boilers cannot use the gas, it is flared.

When the digester gas is used for the thermal dryer, gas collected in the storage tank is first routed through foam separators to remove foam from the gas. Liquid-ring compressors are used to compress the gas to provide constant pressure to the thermal dryer. The digester gas is next routed through a digester gas dryer to remove moisture. Daily digester gas production ranges from 700,000 to 850,000 standard cubic feet per day (scfd); the methane content of the gas is consistently about 58 percent. When in operation, the thermal dryer typically uses 650,000 to 700,000 scfd of digester gas. Use of digester gas in lieu of natural gas to fuel the dryer has resulted in an annual savings of approximately $500,000 of purchased natural gas to fuel the dryer.

PERFORMANCE AND CONCLUSIONS

The Blue Lake WWTP has received the following awards:

- U.S. Environmental Protection Agency (EPA) – Region 5 – 2005 First Place Award – Operation and Maintenance Excellence Award – Large Advanced Plant Category.
- U.S. EPA National Clean Water Act Recognition Awards – 2005 – Second Place – Outstanding Operation and Maintenance – Large Advanced Plant Category.
- National Association of Clean Water Agencies (NACWA) 2013 Platinum 7 Award.
- 2011 Minnesota Safety Council Meritorious Achievement Award in Occupational Safety.

The plant has an excellent operating record, and has perfect National Pollutant Discharge Elimination System (NPDES) permit compliance for the past eight years. CS

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