A Turndown Solution Proves to be City's Upturn

▲ To handle full buildout flows, the MBR system is configured with four membrane tanks, each with capacity to install 224 membrane modules. For startup, two membrane tanks were put into operation and 168 membrane modules were installed in each tank.

Kuna—population 16,000—is located in an agricultural area in southwest Idaho. The city decided to construct a new wastewater treatment plant (WWTP) based on expected population growth. The facility's outfall discharges into Indian Creek, which is a tributary of the Boise River that eventually connects to the Snake River.

By Brett Woods

MBR system helps city meet stringent effluent requirements

Discharges to the Lower Boise River system contain phosphorus, which ultimately impairs the water quality downstream in the Snake River. Total phosphorus (TP) concentrations in Indian Creek are greater than 0.07 mg/L, so the technology Kuna installed would have to meet a 0.07-mg/L TP limit. Other effluent requirements included a five-day biochemical oxygen demand (BOD5), total suspended solids (TSS) and ammonia.

Low-Flow MBR Design

Kuna selected an MBR system from Siemens Water Technologies to help meet the stringent effluent requirements. The MBR system allowed the facility to be designed with maximum flexibility. The system is designed for a maximum monthly flow condition of 3.5 million gal per day (mgd). The anticipated startup flows for the plant were 0.3 mgd—more than a 10:1 turndown of the system.

The MBR system is designed for enhanced biological nutrient removal and consists of two biological treatment trains followed by four membrane tanks. Each biological train has an anaerobic reactor, an anoxic reactor, two fine-bubble aerobic reactors and a post-anoxic reactor. Each membrane tank has capacity to install 224 membrane modules.

Several turndown features were incorporated into the MBR design, including multiple treatment trains, a dual-point mixed liquor return system, temporary installation of mixing equipment, rotary lobe filtrate pumps, partial installation of membranes, multiple versus single pump configurations for turndown and variable frequency drives on rotating equipment.

Only one of the biological treatment trains was put into operation during startup. By keeping one train offline, the plant immediately achieved a 50% turndown of the system, which helped reduce the solids retention time (SRT) of the biological process and reduced the demand for turndown of aeration equipment and pumping systems.

The number of membrane tanks in operation and the number of installed membranes also were reduced for startup conditions. For startup, two membrane tanks were put into operation, with 168 membrane modules installed in each tank. This gave more than 60% turndown of the membrane system, which also helped reduce system SRT as well as the need for equipment turndown.

Operating two versus four membrane tanks helps control dissolved oxygen (DO) and reduce the amount of oxygen input from the membrane system during low flows. Membrane air scouring adds a significant amount of DO to the mixed liquor, which eventually returns to the biological process as a DO credit. At low flows, the DO contribution from membrane air scouring accounts for a large fraction of the overall oxygen demand of the influent waste. This puts additional turndown burden on the aeration equipment of the biological process.

The MBR system was designed with a dual-point mixed liquor return system, which refers to how the mixed liquor is returned to the biological process from the membrane tanks. MBR systems commonly are designed with a single, fixed return location of mixed liquor from the membrane tanks. The most common return location is to the anoxic zone. Returning mixed liquor here works well at full design flows; however, during low flows the high oxygen content of the mixed liquor overloads the anoxic zone, making it impossible to maintain anoxic conditions. This problem is solved by designing the system with an alternate return location, which allows the mixed liquor to be returned to a downstream aerobic zone, thus maintaining oxygen-deficient conditions in the anoxic zone for denitrification.

Mixers were installed temporarily in the aeration basins for startup to allow on/off cycling of the fine-bubble diffused air system while still maintaining mixing. Borrowing the mixers from the second biological train that was offline during startup saved the plant additional costs.

Multiple pump configurations for the nitrate recycle system were incorporated into the facility. Instead of designing the system with one large pump sized for the full buildout recycle flows, each treatment train is equipped with two nitrate recycle pumps. This gives a 4:1 turndown in recycle flow just by taking pumps offline. Additional turndown of the nitrate recycle system was achieved with variable frequency drives on the pumps.

Effluent Performance

Incorporating the above low-flow design features into the Kuna MBR system resulted in excellent performance during startup. Influent flows are based on measured filtrate flow. For the first three months of operation, these flows averaged 0.31 mgd, 0.42 mgd and 0.38 mgd, respectively, which are very close to the predicted startup flow of 0.3 mgd.

The MBR system demonstrated very efficient BOD and TSS removal during low-flow conditions. All measured values for effluent BOD and effluent TSS were reported as less than 3 mg/L during the first three months of operation—well below the average monthly limits of 30 mg/L.

The MBR system was able to maintain efficient nitrification during the low-flow startup conditions. The effluent ammonia levels were consistently low during the three-month startup period, averaging 0.04 mg/L for the months of September and October.

A good indicator of system performance during low-flow conditions is effluent nitrate levels. High effluent nitrate levels are a sign of high DO levels, which means the system is not achieving the required level of turndown. The MBR system had consistent nitrate removal with effluent nitrates and nitrites, averaging 8.32 mg/L in August and 5.97 mg/L in September.

The MBR system also achieved the required TP removal during low-flow startup conditions. Phosphorus removal was accomplished chemically using aluminum sulfate.

Design Success

As Kuna can attest, the most important part of low-flow design for MBR systems is identifying the low-flow conditions during the design phase. If low flows are anticipated early on in the design, the system can be configured with the right turndown capacity to help manage the challenges of low-flow operation.

The biggest challenge with low-flow operation of an MBR plant is the ability to scale down the operation of the biological system and the membrane filtration system to maintain appropriate process conditions such as DO levels, recycle rates and SRT. Depending on the degree of turndown required, the MBR system can incorporate a variety of low-flow design features. Some of these features include multiple treatment trains, a dual-point mixed liquor return system, temporary installation of mixing equipment, rotary lobe pumps, partial installation of membranes, multiple versus single pump configurations for turndown and variable frequency drives rotating equipment.

The city of Kuna incorporated many of these design features as part of its new MBR WWTP in anticipation of treating low flows at startup. During the first three months of low-flow startup, the MBR system was able to exceed all performance requirements for effluent BOD, TSS, ammonia, nitrates and TP. WWD

One of two biological treatment trains and the membrane system process building.

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